The feasibility of using an adapted 24-hour recall method versus skin carotenoids status to assess fruit and vegetable intake in low-income Māori households

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

Master of Science in

Nutrition and Dietetics

Massey University, Albany New Zealand

Dana Young

2022

Abstract

Background: High fruit and vegetables (F/V) intake have been repeatedly shown to decrease risk of developing obesity and non-communicable diseases. Māori people living in deprived areas are often experiencing some degree of food insecurity, which exposes this population to a greater nutritional risk due to lower F/V intake. There is currently no validated instrument to measure F/V intake in low-income Māori households. Finding a feasible dietary assessment tool will be helpful to determine nutritional status and consumption patterns; to assess the association between F/V and diseases; and to guide evaluation for food policies and programs in eliminating barriers to healthy eating.

Aim: To assess the feasibility of an adapted 24-hour (24-h) recalls versus skin carotenoids status to assess F/V intake in low-income Māori households participating in a F/V intervention.

Methods: This feasibility study was conducted in 12 Māori households living in Palmerston North, New Zealand. Intake of F/V were measured by a 24-h recall and skin carotenoid via Veggie Meter © (VM) on four randomised days during baseline, followed by a washout period of five weeks. The intervention study commenced with participants receiving a weekly free box of F/V (enough to feed the entire household according to guidelines). The same measurements were repeated. Feasibility of both instruments were analysed by Pearson and Spearman correlation. Significance was set as $p < 0.05$.

Results: There was no significant difference in the mean total F/V servings across the study. Median servings and intake of fruit were significantly different between baseline and endpoint ($p = 0.05$). Only one (8%) participant met the MoH daily recommendations of 5 servings of vegetables and 2 servings of fruits at baseline, and four participants (50%) at endpoint.

Spearman's rho correlation showed no association between VM scores and self-reported F/V intake (p = 0.50). A significant correlation was found between those with a ≥250 VM score and intake of yellow-vitamin-A F/V and F/V at baseline (p = 0.04) and intervention (p = 0.03).

Conclusion: The developed multiple-pass 24-h recall was a feasible tool to assess F/V intake in low-income Māori income. To improve quality of data collection, more training and support for the research assistants is needed. Measuring skin carotenoids as a method to measure vitamin A F/V is feasible, but may not be the best to objectively measure F/V.

Key search words include "dietary intake assessment", "food security", "fruit and vegetable intake", "24-hour recall", "skin carotenoid", "feasibility" and "Māori health."

Acknowledgement

My deep appreciation goes out to everyone who has supported me since day one of my Masters, and to others that has supported along the way.

To Prof Rozanne, my only thesis supervisor, I would like to thank you for your continuous support and guidance, and pouring extra hours outside of work to help me. With all the crazy obstacles that I have faced in this study and times where I have felt hopeless, thank you for believing in me and that I will be fine and we will get through this together.

To all the other members on this research team, ngā mihi nui ki a koe ! Thank you Geoff and Anette for providing this opportunity to do my thesis and allowing me to be part of your research. Thank you Terewai and Faith for being such amazing research assistants.

To Hajar Mazahery, thank you for giving me the confidence to analyse data, your prompt feedback and support is greatly appreciated.

To all my friends who have cheered me on and encouraged me, thank you. I know many of my friends have said "you're still not done?" well I can officially say I'm done. To my close friends, the tremendous stress we have all traumatically experienced is a memory and life-journey we will never forget. Thank you for riding this wild journey together.

To my family, thank you mom and dad for always supporting me, picking up the phone when I needed a break from thesis and getting me an annual subscription to Grammarly to help with my writing. Thank you to my partner Matt, who tried to help me edit my thesis but your support at the end of the day was most the important. A special thank you to my grandmother who I know you've been looking out for me from above.

Table of Contents

List of Tables

List of Figures

List of Appendices

Appendix A – Supplementary Methods

Appendix B – Supplementary Results

List of Abbreviations

DAPA	Diet, Anthropometry and Physical Activity
FAO	Food and Agriculture Organisation
FCS	Food-coping Strategies
FFQ	Food Frequency Questionnaire
F/V	Fruit and vegetables
HT	Hypertension
24-h	Twenty-four-hour
LSES	Low-socioeconomic status
MoH	Ministry of Health
NZ	New Zealand
NCI	National Cancer Institute
NNS	National Health Survey
SCS	Skin Carotenoid Status
SES	Socioeconomic-status
RA	Research assistant
RRS	Resonance Raman spectroscopy
RS	Pressure mediated reflection spectroscopy
RDI	Recommended Daily Intake
USAD	United States Academic Decathlon
VM	Veggie Meter
WHO	World Health Organisation

Chapter 1- Introduction

Across New Zealand (NZ), a high number of people do not meet the recommended daily intake (RDI) of fruit and vegetables (F/V). According to the NZ Ministry of Health (MoH) 2021 Health Survey, only 51% of adults met the recommended vegetable intake, and only 48% met the recommended fruit intake. Inadequate F/V intake increases the risk of coronary heart disease and obesity, which are among the top 10 risk factors contributing to mortality (WHO, 2020). The American Heart Association stated that consuming five servings of F/V per day has a 13% lower risk of mortality from all causes (Wang et al., 2021). However, changes in the environment and behaviours, such as the increase in the availability of cheap convenience foods; the high cost of F/V, and replacing F/V with energy-dense foods have reshaped today eating patterns.

Economic access to healthy foods and healthcare is the main contributor to health inequalities, which has led to a rise in non-communicable diseases among vulnerable populations (Drisdelle et al., 2020), particularly Māori people (Ministry of Health, 2020). For example, children living in socially deprived areas are 2.7 times more likely to be obese than children living in less deprived areas (Ministry of Health, 2020). Likewise, adults living in less deprived areas are 1.6 more likely to be obese (Ministry of Health, 2019a). Obesity rates among Māori adults are 48% compared to 29% of NZ European adults, and similarly, Māori adults are 1.8 times more likely to be obese than non-Māori (Ministry of Health, 2019a). According to the MoH report, there is no known level of F/V intake associated with a lower risk of obesity and non-communicable diseases; however, the minimum amount of F/V for prevention for all ages, gender and ethnicity is 600g ± 50g of F/V (based on WHO report 2002) (Ezzati et al., 2002). Nevertheless, cardiovascular disease mortality rates are five times higher in Māori than non-Māori (Ministry of Health, 2014). These discrepancies must be addressed to improve health outcomes for Māori.

In this study, “low-income” is defined as those who are living in Q4-Q5 zones (Q1- least deprived, Q5 - most deprived from the New Zealand Index of Multiple Deprivation 2018) which relates to being deprived in multiple areas including employment, income, crime, housing, health and education (University of Auckland 2018).

Dietary intake assessments are used for many purposes and are essential for health promotion, epidemiological and nutrition intervention-based research. Currently, many dietary intake instruments may not be feasible, acceptable or able to accurately estimate F/V intake in Māori living in deprived areas (DeBiasse et al., 2018). Very few studies have examined F/V intake in both Māori and low-income populations in NZ. The 24-hour recall (24-h recall) is the most commonly used dietary assessment method in evaluating the diets of populations because it enables estimating absolute intake rather than relative intake (DeBiasse et al., 2018). Furthermore, because it is cognitively easy (MRC, 2020) and can be tailored to be culturally sensitive, the 24-h recall is easy and a low burden for people with limited literacy skills (Gibson et al., 2008). A trained interviewer conducts the 24-h recall to assess food and beverage consumption in the past 24 hours to capture the actual intake of foods. However, it heavily relies on an individual’s memory as well as the skill and persistence of the interviewer to obtain accurate dietary information (Bulungu et al., 2021). Food frequency questionnaires (FFQ), food records, web-based software and smartphone recording applications are other subjective instruments, but they all have similar limitations - respondent bias and memory dependence (DeBiasse et al., 2018). Such limitations can lead to under-reporting or inaccurate portion estimation resulting in measurement errors, and potentially falsely detecting associations between diet and disease, thus fabricating data in epidemiology (Poslusna et al., 2009).

On the other hand, objective methods like a biomarker, can overcome those measurement errors inherent of self-reported intake and provide an additional parameter of nutritional status. Spectroscopy-based skin carotenoid measurements are emerging as an objective approximation of F/V consumption because it is cheap, fast and noninvasive. Therefore, the question is, which are the most feasible dietary assessment methods to be used to measure F/V intake in low-income Māori groups that would ensure the most accurate data are collected to understand the relationship between F/V intake and Māori health.

1.1 Purpose of the study

Eating a variety of food and meeting the minimum requirements of F/V intake is a global strategy to reduce the risk of developing major non-communicable diseases (Hosseinpoor et al., 2012). Price is often a big barrier to eating healthy, however, barriers related to food insecurity (food accessibility affordability) is a bigger problem (Mackay et al., 2018). Before approaching policymakers to reduce undernutrition, we must first understand the dietary intake and eating patterns at an individual, household, and population level first. Currently, there is no validated tool to best measure F/V intake in a culturally safe way, in this case, among a Māori population living in high deprived community. Thus, this study aims to determine the feasibility of two dietary assessment methods, namely an adapted, tested 24-h recall method vs a skin carotenoid status (SCS) measurement for assessing F/V intake in Māori households living in a low-income community in Palmerston North. Validating such dietary intake tools can contribute toward accurate data collection in epidemiological studies, evaluating health promotional programs and policies, building a more sustainable food network for whānau living in poverty and, most importantly, improving health outcomes and Hauora (well-being) in Māori communities.

Aims

To conduct a feasibility study of two dietary assessment methods - an adapted 24-h recall versus skin carotenoids status measurement to assess fruit and vegetable intake in Māori households living in Palmerston North, participating in a fruit and vegetable intervention feasibility study.

Objectives

1. To develop a 24-h recall method to be used by Māori research assistants to collect F/V intake data from Māori households.

2. To train the Māori research assistants to conduct the 24-hour recall.

3. Evaluate and compare the F/V intake at baseline and end of intervention with the New Zealand Eating and Activity guidelines.

   ***Hypothesis One*:**

   There will be no difference in F/V consumption pre- and post-intervention due to the potential behaviour barriers such as time, taste, personal preference, fixated habits, attitudes and beliefs towards F/V, and food and nutrition knowledge deficit.

4. Describe the F/V intake in a low-socioeconomic Māori population pre- and post-intervention using the 24-h recall method.

5. Assess the effectiveness of the 24-h recall method by comparing the change in fruit and vegetable intake with the change in skin carotenoid status.

   ***Hypothesis Two*:**

   The re-adapted 24-h recall method will be a feasible tool to capture dietary data. The use of both subjective and objective methods, the 24-h recall and Veggie Meter, will be reliable tools when used in conjunction for assessing the accuracy of 24-hour food recall in a low-socioeconomic Māori population.

Structure of the thesis

This literature review will explore four main topics, food insecurity, fruit and vegetable (F/V) intake, dietary assessment and dermal carotenoid spectroscopy. The first section will explore food insecurity and its association with health outcomes in Māori. The second section will explore the importance of F/V intake and the barriers to consumption in low-income households. The third section will investigate the research around the validity of different dietary assessment methods. The last section will examine skin carotenoids as a biomarker to determine F/V intake and existing evidence around using both methods.

Researcher Contributions

Table 1 *Research contributions to this study*

Research Team	Contribution to thesis
Dana Young	Main researcher and author including the development of the 24-h recall method, training and resources. Statistical analysis and interpretation, writing, editing and final preparation of thesis.
Prof Rozanne Kruger	Co-investigator of the main study. Main academic supervisor, assistance with developing 24-h recall tool, training with the research assistants, editing and final presentation of the study.
Dr Geoffrey Kira, Dr Anette Kira	Lead investigator of the main study. Concept and research design and ethics approval.
Terewai Simmonds, Faith Mataki	Research Assistants responsible for participant recruitment and execution of all dietary assessment tool data collection.

Chapter 2 - Literature Review

2.1 Food Insecurity

Food insecurity is defined by the New Zealand (NZ) Ministry of Health (MoH) as “limited or uncertain availability of nutritionally adequate and safe foods or limited ability to acquire personally accepted foods that meet cultural needs in a socially accepted way.” According to the 2008/09 NZ Adult Nutrition Survey, 39% of Māori men and 35% of Māori women living in households are fully food secure, which implies more than 50% of Māori are experiencing moderate to high food insecurity (University of Otago & Ministry of Health2011). Further studies highlighted that one in four Māori adults and children live in low-socioeconomic status (LSES) households (Beavis et al., 2019); furthermore, Māori are three times more likely to be living in the most deprived neighbourhood compared non-Māori (Atkinson et al, 2014). Such socio-economic hardship experienced by Māori may leave them feeling more stressed as they cannot provide and purchase sufficient food.

While causation of food insecurity is complex, financial constraint is often the central causation that can lead to people relying on food banks or experiencing starvation. While eating healthy food can be viewed as more expensive by Māori and Pacific; according to Mackay (2018) study, switching to a more nutritious meal and purchasing vegetables do not incur additional costs. This indicates cost is not necessarily a barrier but other such as taste, preference, convenience, knowledge, psychosocial stress, accessibility, and cooking skills are equally recognised barriers to eating healthy (Mackay et al., 2018). Conversely, these barriers are also constructed by political and social systems that stem from colonisation and ongoing institutionalised racism

(Reid et al., 2007). Such changes in the social environment, including differential access to healthy foods and healthcare are directly connected to poorer health outcomes (Reid et al., 2007).

2.1.1 Food insecurity and health outcomes

The Māori ethnic group faces an inequitable burden of obesity and associated non-communicable diseases such as cardiovascular diseases, diabetes, and chronic respiratory diseases (Hosseinpoor et al., 2012). For example, adults living in low-socioeconomic deprived areas are 1.8 times more likely to be obese (Ministry of Health, 2020), and heart failure hospitalisation was four times higher in Māori than non-Māori (Ministry of Health, 2019b). In the 2019 Māori Health Trends Report, the self-reported prevalence of diabetes remained about twice as high in Māori than non-Māori between 2006-2017 (Ministry of Health, 2019b).

Studies hypothesised that food insecurity predisposes LSES individuals to obesity and diabetes (Mello et al., 2010; H. K. Seligman et al., 2010) because: 1) cheap foods tend to be calorically dense, which increases the glycaemic load; 2) their day-to-day changes in food availability can highly impact blood sugar levels (Lyles et al., 2013; Mello et al., 2010). Another study also confirms that the association between food insecurity and diabetes is more significant than hypertension for several reasons (Seligman et al., 2010). Firstly, diabetes can go misdiagnosed because people forego seeing a doctor due to visitation cost; and second, food insecurity can be very stressful, which increases cortisol levels linked to adiposity, increasing the risk of diabetes (Seligman et al., 2010). While inadequate income can negatively impact an individual's health and well-being, the food environment also plays a significant role. The food environment is defined as "the collective physical, economic, policy, socio-cultural surroundings, opportunities and conditions that influence people's food and beverage choices and nutritional status" (Swinburn, 2014).

New Zealand’s current food environment is largely characterised by widely promoted and easily accessible energy-dense food products containing high levels of salt, sugars and saturated fats, such as lollies, high-processed snacks and fast food (Swinburn, 2014). Rather than blaming individuals for eating healthily, it is essential to focus on addressing the food supply and environment that is heavily shaped by the government, food industries and societal mechanisms. To reduce the prevalence of obesity and its related inequalities, effective government policies will require a range of actions to improve the food environment. Considerations should be given to include an excise tax of at least 20% on sugar-sweetened beverages; increase funding for national nutrition promotion; meeting dietary guidelines in all schools and early childhood centres, and reducing advertising and promotion of unhealthy foods (Swinburn, 2014). An NZ study showed that 77% of NZ sectoral professionals agree that sustainability recommendations should be included in current Eating and Activity Guidelines for NZ adults, with 90.7% favouring limited processed foods and 93.6% favouring promoting seasonal food produce (Jones et al., 2019). Whilst studies are trying to deliver long-term solutions, more studies are needed to investigate how individuals and communities interact with the local food environment to make health policies and programs more effective and realistic.

2.1.2 Food insecurity from a Māori perspective

Food insecurity is a complex issue and thus requires insights into Māori communities who live in food-insecure households to better understand how to address specific nutrient, health and cultural interventions (Moeke-Pickering et al., 2015). The following insights are provided. Households facing food insecurity develop food-provisioning tactics or food-coping strategies (FCS) to stretch available food sources to keep the family fed. For example, buying food with credit, borrowing food, and altering diet with low-cost foods (Buck-McFadyen, 2015; Kruger et al., 2008). Koha Kai (gifted foods from whānau) is common in LSES Māori households, and it also presents an expectation to reciprocate the behaviour (Beavis et al., 2019). Other cultural behaviours around kai are presented in Table 2.1. They will often feel pressured because they have no food to give back, hence churches often step in with frozen meals to help these families (Beavis et al., 2019). A local study on LSES Māori households found that giving out a free box of fruit and vegetables (F/V) was helpful in alleviating their food cost and reverted that money to pay for transportation for family-based activities (Beavis et al., 2019). Another study followed a single Māori household living in poverty, and the family reported using multiple streams of food sources to navigate food insecurity, such as buying the cheapest deals from multiple grocery stores, churches, charitable meals, welfare agencies, food banks, and surplus from extended whanau networks (Graham et al., 2018). Rural households in Canada also reported similar tactics by turning leftovers into stews, soups and casseroles, stocking up on sales items, fishing, hunting and harvesting fruit as food procurement strategies (Buck-McFadyen, 2015). These hardships are often associated with poor health and mental health; life-dissatisfaction; a weak sense of belonging, and well-being (Willows et al., 2011). The narrative of food insecurity should not solely focus on financial constraints (Beavis et al., 2019; Glover et al., 2019), but a shift toward the broader economic, political and social scene that contributes to financial hardships.

Growing F/V have been traditionally used to alleviate food insecurity Māori household. However, land restrictions and tenancy rules makes it difficult for Māori to maintain gardening knowledge learnt from past generations (Beavis et al., 2019). Food access like harvesting kai moana (food from the sea, e.g. fish and shellfish) is also restricted due to quotas. These land restrictions and fishing quotas are other barriers to healthy eating. Other health barriers are presented in Table 2.2. It is important to recognise that gardening, fishing and harvesting are ways for these families to engage in traditional practices and the value of kaitiakitanga (care for the environment and sustainability) and Hauora (well-being) (Beavis et al., 2019). Moreover, the participants in the Moeke-Pickering study (2015) recognised that eating processed foods were a barrier to their overall health and Hauora, as well as their confidence to reclaim their land for sovereignty. The land is given to Pākehā to grow maise instead of giving the land to Māori to educate the younger generation on how to care, grow and prepare Māori kai. A supply depletion due to the pollution has placed strict quotas on kai moana. Therefore, the limited access to traditional kai has resulted in reliance on supermarkets and cheap food outlets for kai (Moeke-Pickering et al.,2015). The experiences that Māori face with food insecurity are a reflection of the unequal access to their own Māori cultural values such as Hauora and whānaungatanga (Beavis et al., 2019). This emphasises that financial constraint is a small part of the problem. Impact of colonisation on land and environmental inaccessibility continues to inhibit Māori food sovereignty.

Inaccessibility to land means that the local food system and its connection to Māori Health is deteriorating. The protection of kai from the garden is a significant value to preserve Māori life and culture as it re-connects to their ancestors and environment. For Māori, gardening is viewed as an interconnection between the spiritual world and the natural environment. Traditionally, gardening was based on kaitiakitanga, which is responsible for producing food that protects its integrity of resources and safeguarding its mauri (life-force) and the environment (Viriaere et al., 2018). Nowadays, the excessive availability of convenience foods has made it challenging for Māori to maintain the connection between kai and traditional practices (McKerchar et al., 2015). Consequently, Māori are experiencing higher levels of non-communicable disease, and this can be addressed through dietary change using a holistic view of health by revitalising gardening traditions as an integral component in improving Māori health outcomes (Viriaere et al., 2018).

Table 2.1 *Māori cultural behaviours and experiences around kai and Hauora*

Study	Cultural behavioural considerations on food and health
(Beavis et al., 2019).	• Gifting and sharing to extended whanau are a form of expressing manākitanga (hospitality) and a strategy to reduce the severity of food insecurity. If they cannot afford or reciprocate hospitality, it can negatively impact whanau's Haora (well-being). • Kaitiakitanga – caring for the environment enables Māori to connect to the land. Sharing surplus supplies to whanau provides a positive hauora. Having the traditional knowledge to maintain a sustainable food supply must be passed on to future generations. • It is important to pass down cooking skills and traditional kai knowledge.
(Glover et al., 2019)	• Mannakitanga (process of showing respect, generosity and care) protocol – leaving guest full and this respect is reciprocal. Hence, it is common to purchase $100 worth of cheap foods when hosting parties and events. • Loss of traditional skills and knowledge but it has been improved at community level e.g., Marae and church provide healthy kai, arrangement with farmers and access to land to hunt and harvest. • Participants were not knowledgeable about obesity and thought children under age of 5 was not a major health problem and that once in school, their physical activity increases and will burn off excess fat and naturally grow into their body. • In the old days, kids can grab excess fruits from neighbour's fruit trees. But now, neighbours' yells "Hey! What are you doing!?". Cultural shift towards individual ownership vs. sharing.
(Moeke-Pickering et al.,2015).	• Healthy lifestyle is depicted as māra kai, seafood and fruit orchards; gathering, preparing, planting and sharing of kai. Kai is medicine itself that is good for the spirit and body, and a connection to ancestors, history & the land. • Seed saving is about tikanga and knowledge, replanting and sharing seeds shows the reciprocal care with the land and future generations (manaakitanga).
(Lanumata T, 2008)	• Having role models and real-life stories, especially someone from their own community who has succeeded is major in supporting Māori to eat the food needed for a healthy lifestyle. It was equally important for Pasifika to have support groups starting at a community level like churches to educate people about healthy eating. Gathering families and looking after each other families is an important Pacific cultural value. • Participants felt that planting seeds and growing their own foods is better than relying on supermarkets or food banks, but growing requires time and skills like planting or preparing food from scratch becomes discouraging. • Excess produce was gifted to whanau during difficult situations.

Table 2.2 *Health barriers to fruit and vegetable intake in low-income and Māori population*

Study	Barriers to F/V intake	Participant's perspectives on barriers to health
(Beavis et al., 2019).	Hardship and mental strain	• Forfeit fresh F/V, birthday parties and whanau gatherings to stretch household food money. • Putting their child's health and needs first and starving themselves.
	Gardening	• Landlords did not allow tenants to grow F/V, create a vegetable garden or extend garden plot.
	Teaching food and nutrition skills	• Gaining confidence and learning how to cook from parents and grandparents. Participants felt if they fed their children fast food all the time, passing on food knowledge and skills could be lost. • Afraid the long-term effects of food insecurity can impact their child's taste preference and health
(Moeke-Pickering et al.,2015).	Experiencing food shortages due to the impact of colonisation	• Māori participants identified fast-food, being overweight, being prescribed too many medications for heart disease & other illness. • Other barriers reported: poverty, income inequity, obstructed access to traditional land and food, deprivation in food development, lack of educational programs, living in urban settings with a faster lifestyle high dependency on supermarket that sells energy-dense foods at a cheaper price.
(Glover et al., 2019)	Contemporary pressures undermining Māori values	• Eating healthy has to be "fresh" and "organic", e.g., does not want to use sugar in baking because it is "refined" but can't afford honey or maple syrup, thus feels guilty for not able to feed child healthily.
	Budget to feed whanau and satisfy their taste and satiety	• Buying a $1 pie is cheaper, more filling and taste satisfying than buying healthy foods. • "Feast and famine": Pay day allows them to eat healthy for 1-week, then its 3-weeks of eating "crap".
	Role of whanau	• Grandparent's role is to treat grandchildren. Parents on tight food budget cannot refuse when whanau are feeding their child "junk food" or "treats".
	Time constraints to cook	• Learning what is healthy food, how to cook and prepare, read nutrition labels and recipes under 15 minutes will be helpful, especially for larger households with a big appetite.
	Accessibility, availability and affordability	• Foods from food parcels or food banks are usually expired. • Food grants are often begged to be exchanged to cash to pay electricity bill.
	Lack of understanding and limited education on healthy eating	• Many complained that the ingredients used on cooking shows are foreign and unaffordable to them, "Parents didn't teach us how to cook food the way we see it on television.". • They felt they didn't know what healthy eating looks like, how to cook tasty nutritious meals, what are portion sizes and don't understand food labels. They all felt that buying healthy foods are expensive.
	Accessibility and availability	• Those living in rural areas grocery shop once a week and freeze everything. Dairy shops are expensive and F/V are old and not fresh. Petrol price has increased, making it more expensive to run the car, and no buses in rural areas. • Urban settings are surrounded by cheap & unhealthy outlets. They know its unhealthy but it's cheaper.

2.2 Fruit and vegetable intake

The 2020-21 NZ Health Survey results showed that only 30% of New Zealanders and 28.2% of Māori had met the F/V intake guidelines (3+ servings of vegetables and 2+ servings of fruit per day) (Ministry of Health 2021a). This means more than two-thirds of New Zealanders do not eat the recommended quantity of F/V. Additionally, there has been a 14.3% decline in F/V intake in the past decade (Ministry of Health 2021a) and a decrease of 12% of Māori adults meeting the recommended guidelines from 2006-2017 (Ministry of Health, 2019b). Jaeger and Bava (2009) investigated fruit consumption in high deprivation groups in Auckland and found that the average fruit intake in this population was 5-6 servings per week. Around 10% of participants did not consume fruit weekly, and 38% did not have fresh fruit at home and would instead drink 1-2 glasses of 100% fruit juice per week (Jaeger et al., 2009). One limitation when measuring F/V intake is the consideration of “fruit juice” as it is energy dense and has a low fibre content, hence whole fruits are preferable (National Health and Medical Council, 2013). Nevertheless, New Zealanders are not eating enough F/V to achieve optimum health.

2.2.1 Importance of fruit and vegetables for health outcomes

2.2.1.1 Why eat fruit and vegetables?

Vegetables and fruits are nutrient-dense, relatively low in energy, and a great source of fibre, minerals, vitamins and many other bioactive compounds that can positively promote health and growth, support the development of children and reduce nutritional deficiencies (Slavin et al., 2012). Diets high in F/V are widely encouraged for their health promoting properties. They have been historically emphasised in dietary guidelines due to their high concentration of vitamin A & C, minerals and, more recently for their antioxidant properties. For example, the 2020-2025 Dietary Guidelines for Americans recommends 2.5 cups of vegetables and 2 cups of fruit per day

(USDA, 2020). Apart from this, F/V are also high in dietary fibre that help delay gastric emptying and increase absorption of nutrients, thereby assisting with stool bulking and laxation (Rush et al., 2019).

The two major types of fibre are soluble and insoluble fibre. Soluble fibre is dissolvable in water, forming a gel-like consistency that binds with cholesterol-rich bile in the digestive tract, thereby lowering overall serum LDL-cholesterol levels (Lattimer et al., 2010). In contrast, insoluble fibre is not dissolvable in water, which increases the rate of food moving through the digestive tract, promoting regularity and appetite reduction that can be beneficial for weight management (Lattimer et al., 2010). Diets high in fibre are linked with cancer prevention, weight management and a lower risk of cardiovascular diseases and diabetes (Kendall et al., 2010). Moreover, an additional 10g of fibre in the diet can decrease the mortality risk from heart-related disease by 17-35% (Streppel et al., 2008). F/V also assist with combating micronutrient deficiencies from its bioactive compounds such as carotenoids, flavonoids, flavanols and phenolics found in tomatoes, capsicum, lettuce, onions, broccoli, watermelon, citrus fruits etc. (Rush et al., 2019). Other properties such as inulin and fructo-oligosaccharides found in garlic, asparagus, tomatoes, bananas etc., have been shown to act as a prebiotic, stimulating the growth of *bifidobacteria* whilst preventing harmful pathogens such as *E.coli and Listeria* (Lattimer et al., 2010). In one study, inulin supplementation increased calcium absorption by 20%, whilst inulin can stabilise blood glucose concentrations and promote overall gut health and immunity (Al-Sheraji et al., 2013). Ultimately, different colours and variety of F/V offer a range of phytochemicals and antioxidants such as vitamin C, vitamin E, beta-carotene, selenium and zinc, which can protect against oxidation of cholesterol in the arteries; improve endothelia functions; lower blood pressure and risk of Type-2 diabetes (Pienovi et al., 2015; Wedick et al., 2012). Overall, each nutrient in F/V plays a role in disease prevention, but their synergistic effect plays a wider health benefit.

2.2.1.2 Health benefits of eating fruit and vegetables

Eating more water-rich vegetables (green leafy vegetables) over energy-dense foods can reduce overall energy intake; increase nutrient density, and satiety that improves overall dietary patterns and body weight maintenance (Ministry of Health, 2003; Rush et al., 2019). By increasing 80g/day of F/V into the diet, the MoH has modelled that 4–20% of ischaemic heart disease deaths; 3–11% of ischaemic stroke deaths; 2–10% of lung cancer deaths, and 3–17% of stomach cancer could be avoided (Ministry of Health, 2003). The American Heart Association, reported that nearly two million adults worldwide who consumed five servings of F/V per day had a 13% lower risk of mortality from all causes. This includes a 12% lower risk of death from cardiovascular diseases; 10% lower risk of death from cancer, and 35% lower risk of chronic respiratory diseases (Wang et al., 2021). People with a high F/V intake are likely to obtain other healthy behaviours, such as frequent physical activity, no smoking and consuming less high-processed foods (Bazzano et al., 2002). Overall, more studies are showing more robust evidence for the benefits F/V brings to lower risk of overall mortality, cardiovascular disease, hypertension, diabetes, and several types of cancer (Aune et al., 2017; L. Schwingshackl et al., 2015; Slavin et al., 2012).

2.2.1.3 New Zealand Dietary Guidelines

The MoH has recently changed the Eating and Activity Guidelines for NZ adults to adapt to the current health landscape and nutrition needs of New Zealanders. Current NZ guidelines for vegetable serving sizes have increased from three to five servings / day, while fruit serving sizes remained the same at two servings / day (Table 2.3). Therefore, the recommended guidelines for

F/V have increased from five to seven servings. Nonetheless, the WHO recommends at least 400g of F/V per day (excluding starchy vegetables) (WHO/FAO, 2003).

Table 2.3 *Current Eating and Activity Guidelines for New Zealand Adults: New Serving Size Advice (Ministry of Health 2020)*

Vegetable A standard serve is about 75g Five servings/ day	Fruit A standard serve is about 150g Two servings/ day
For example: • ½ cup of cooked vegetable (e.g., puha, broccoli, green beans, carrots, silver beet, cabbage, watercress, taro leaves, kamokamo) • ½ medium sized potato, kumara, taro, cassava, green banana, taewa • ½ cup canned vegetable (e.g., sweetcorn, green beans, beetroot, tomato) • 1 cup raw leafy vegetable or salad • 1 medium tomato	For example: • 1 medium sized apple, orange, banana, pear • apricots, mandarins, plums, kiwifruit • 1 cup frozen fruits • 1 cup tinned fruits

The National Health and Medical Research Council (MRC) provided a modelling system and evidence-based report in 2011 for Australia and NZ to update serving sizes advice. Only recently, NZ adopted similar recommendations from Australia's revised 2013 dietary guidelines (Ministry of Health 2020). The evidence for the health benefits of consuming F/V, including beans/legumes, has strengthened over the last decade, particularly protective against cardiovascular diseases such as ischemic heart disease and ischaemic stroke (Dauchet et al., 2006; Zhan et al., 2017). Furthermore, evidence continues to show moderate association in reducing the risk of some cancer types such as lung, stomach, and colorectal cancer (Aune et al., 2017; He et al., 2007; United States Department of Agriculture, 2014).

2.2.2 Barriers to eating fruits and vegetables

There are many health benefits to eating F/V but there are equally as many barriers to achieving the new F/V serving size guidelines. These barriers are multidimensional, including personal influence and the outer dimension of an individual's environment. People's eating decision is not solely reliant on their physiological or nutritional needs but largely influenced by their internal and external environment (Table 2.4) (Wallace et al., 2019).

Table 2.4 *Determinants of food choice adapted from EUFIC (The European Food Information Council 2006)*

	Determinants	Examples
Internal environment	Biological	Hunger, appetite, taste
	Attitudes, beliefs and knowledge about food	Quality, freshness of food, price, taste, health, nutrition, convenience
	Psychological	Mental health, mood, stress, guilt
External Environment	Social / Behavioural	Parents, different priorities throughout life stage, culture
	Physical	Access, education, cooking/gardening skills, housing, time
	Economic	Income, affordability, availability
	Environmental	Climate change, seasons, advertisements, champaigns

2.2.2.1 Internal Environment

Dietary habits begin in childhood and get established in young adulthood; however, young adults (aged 18-24 years) lose interest in maintaining a healthier diet during significant life changes, such as school, careers, marriage and building a family (Alkazemi et al., 2021). The habit of low F/V consumption and a lack of exposure to a variety of F/V throughout early childhood can lead to disliking the taste and unwillingness to experiment with new F/V, which becomes more challenging to adapt in adulthood (Carty et al., 2017).

Interpersonal factors such as taste and personal preference have been highlighted as self-barriers. For example, Kehoe's study (2019) found that women in rural India only like certain vegetables, and many Indian indigenous plants grown nearby were perceived as "dirty" and "unhealthy" amongst the young generations. In Alkazemia and Salmean's study (2021), about 35% of university students in Spain (n = 300) found vegetables unappetising, whilst only 25% liked the taste of F/V, and more than 50% of students thought F/V would rot before consumption. Several students reported wanting more ideas on how to prepare and cook F/V.

One NZ study removed the "affordability-accessibility" barrier in LSES households by providing a box of free F/V to explore other barriers hindering their F/V intake (Carty et al., 2017). Barriers found included: 1) not eating F/V in early life due to growing up in a low-income household; 2) limited labour to prepare the vegetables; 3) not wanting to try new vegetables in the box as some preferred eating vegetables in a certain way e.g. stewed rather than raw (Carty et al., 2017). Other factors were mental-health related, such as stress from financial burden and threats of domestic violence which hindered their ability to prepare and eat F/V (Carty et al., 2017). The only households in Carty's study (2017) that benefitted from the intervention the most were those who grew up eating fresh F/V and were motivated.

In Dibsdall's study (2003), participants perceived that eating more F/V requires additional expense, time, and psychological effort, rather than simply exchanging habitual intake with healthier options. Thus motivation, psychosocial and lifestyle factors place a bigger threat on eating F/V (Dibsdall et al., 2003). As a result, behaviour theory has been applied to studies to improve peoples' F/V consumption by addressing the behavioural, psychological, attitudes, beliefs, and knowledge determinants of food choice. For example, Shankar et al. applied behaviour theory to nutrition education for African-American women living in public housing (n = 212) to improve F/V intake. This involved building self-efficacy for nutrition-related problem solving and cooking skills (Shankar et al., 2006). However, no significant change in their F/V intake was observed after receiving six 90-minute nutrition classes (Shankar et al., 2006). A systematic review showed that the F/V intake in minority and low-income groups averaged 0.97

servings/day, and the use of behavioural constructs from self-determination theory, social cognitive theory and ethnic identity theory did not improve their daily servings of F/V (Thomson et al., 2011). Perhaps behaviour theory is not effective in achieving a sustaining F/V intake but requires addressing other barriers such as cost, accessibility, availability and perceived value of adopting healthier food choices (Thomson et al., 2011).

2.2.2.2 External Environment

The environment contours how people eat and what foods are available. Today's food environment is made up of food swamps (unhealthy foods are more available) and food mirages (healthy foods are available however unaffordable) (Drisdelle et al., 2020), creating a new eating environment that fosters food preferences inconsistent with the dietary guidelines (Wallace et al., 2019). Students in Kuwait reported they did not buy F/V because local stores and cafeterias lacked selection and freshness (Alkazemi et al., 2021). Regardless, more than 75% of students admitted to buying other foods, even if F/V was available. In rural parts of India, Kehoe et al. (2019) discussed environmental and practical factors were barriers to eating F/V, such as land and water availability to grow F/V; lack of freezers; access to weekly markets; cost of transportation, and price inflation. A similar study conducted on Hispanic immigrant's in the USA found that barriers to eating F/V included: 1) inaccessibility to grocery stores; 2) a lack of cultural foods in store; 3) the US culture including stressful working environments; 4) poorer quality of F/V than the home country; 5) heavy persuasive advertising for fast food coupled with increased price of F/V (Yeh et al., 2008). On the whole, the interaction between the external and personal environment can dramatically change one's eating behaviour.

Furthermore, Dibsdall et.al. (2003) found that both low and high-income groups in the UK did not meet the recommended servings of F/V; and that an increase in income did not necessarily result in an increase in diet quality. In the same study, 67% of low-income participants (n = 680) did not feel money constraints prevented them from eating healthy rather, the promotion of energy-dense foods outweighed wholesome foods. (Dibsdall et al., 2003). This shows that eating F/V is contextual to an individual’s environment, such as city planning, education, economic support, policies and lifestyle changes, all of which are accompanied by mental strain and are plausible barriers to health. Therefore, health promotion campaigns and health professionals should educate people on ways to exchange food items bought for healthier options that do not require additional effort, time and cost. Moreover, localising the solutions specific to the community’s interaction with the food environment is key. Hence, improving F/V consumption in low-income Māori groups will require a collaborative effort to integrate Māori’s holistic view of health and community gardens, which have been shown to strengthen food security by reviving traditional kai (McKerchar et al., 2015; Stein et al., 2018).

2.3 Dietary Intake Assessment

Food intake assessment is essential for assessing nutrient adequacy and nutrition research to plan health interventions and programs effectively. Researchers use a variety of dietary assessment instruments to assess group or individual level food intake, for example a 24-h recall, foods frequency questionnaire (FFQ), 3-day food diary, web-based surveys and cameras etc. The most common instruments to measure national F/V intake are the 24-h recall, FFQ and the National Cancer Institute (NCI) F/V screener (Thomson et al., 2011). Correspondingly, the NZ National Nutrition Survey (NNS) used a multi-pass 24-h recall and dietary habit questionnaire (University of Otago; Ministry of Health, 2011). Out of all the dietary assessments, a FFQ is the most effective in evaluating population-based interventions as it has the ability to rank intake, and be administrated on a large scale due to its low respondent burden (Kim et al., 2003). In contrast, a

FFQ can lack precision and accuracy depending on its structure and length. All these listed instruments are traditional methods in measuring diet.

As mentioned earlier, a diet high in F/V offers many health benefits, but the problem of how to best measure F/V intake in LSES Māori population remains unresolved. Reasons for needing a feasible instrument in low-income groups is due to the prevalence of low literacy, numeracy and language skills that could hinder the ability to complete a dietary record (Holmes et al., 2008). Moreover, there is a higher incidence of mental health issues in low-income groups, such as alcohol and drug use, domestic chaos and stress, which not only hinders memory recall for dietary assessments that decreases quality of data, but also impacts on the safety and welfare of the interviewers. Therefore, a validated dietary intake assessment for low-income groups have been researched (Table 2.5) to improve the quality of data, and be used to investigate diet-health relationships to inform policy, nutrition, health and agricultural programs (DeBiasse et al., 2018; Holmes et al., 2008)

Table 2.5 *Results and limitations of feasibility and validity studies on dietary intake instruments*

Study	Aim	Dietary tools	Results	Discussion	Limitations
Cross-Sectional Design					
DeBiasse et al. (2018) English-Spanish speaking women aged 18-72 yrs. living in public housing (n=29)	To evaluate the feasibility and acceptability of two self-report measures of diet	• 24-h recall • 110 item FFQ	• The retention of two 24-h recall and FFQ was 89% and 91%, respectively. • For acceptability, 35% preferred 24-h recall and 35% also preferred FFQ. • Many participants enjoyed the 24-h recall as they learned about portion sizes and was able to reflect on their diet. • Those who favoured FFQ enjoyed the format as it had more food choices and made them reflect on their eating habits. • Both methods were acceptable and feasible for this population	• Length of time of FFQ was too long. • Did not like personal questions, i.e. "Do you smoke". • 24-h recall was more accurate in capturing current intake. • FFQ ccaptured annual intakes which reflects habitual intakes, including rarely consumed food, e.g., once per year.	• FFQ did not capture cultural food. • Conductor did not follow standardised protocols. • Dietary tools need to be culturally appropriate both verbal and written to prevent language barrier.
(Lins et al., 2016) Low-income, socially vulnerable mothers in Brazil (n=67)	To assess the accuracy of the 24-h recall and the FFQ method in socially vulnerable women in Brazil and compare them against DLW	• Three 24-h recalls • One FFQ • DLW	• Mean energy intake was significantly lower in 24-h recall than the FFQ, 1848.6kcal and 2,084.5kcal, respectively. • On average, underreporting of energy intake was 377kcal in 24-h recall and 93kcal in FFQ. • A positive relation between body fat percentage and underreporting in FFQ ($r = 0.245$; $p = 0.046$).	• The reported energy intake was more accurate in the FFQ by 93kcal than the recall. • Both methods may not be the most suitable for this population since they showed inadequate precision compared to double labelled water	• Did not consider seasonal variability • Unable to detect covariates and misreporting.
(Holmes et al., 2008)	To compare the validity and	• Four multipass 24-h recall	• 24-h recall and food checklist typically yielded higher energy and nutrient intake across all age	Interviewers ranked the methods based on burden and the most accurate	

Study	Aim	Dietary tools	Results	Discussion	Limitations
Low-income households in UK (n=235)	accpetability of three dietary survey methods against appropriate reference measures and to identfy a method that is both valid and acceptable in low-income households	• Food checklist • Semi-weighed method • Weighed inventory	groups, and semi-weighed method yielded lower estimates. • 46% of respondents preferred food checklist and 29% preferred 24-h recall as it was easy and required no writing. • 21% respondent preferred semi-weighed as they found it interesting, enjoyed using scales and made them reflect on their eating/drinking. • 24-h recall provided the most consistent results between all ages and sex groups.	method to reflect true intake: • 75% preferred 24-h recall and 12% for both food checklist and weighed inventory method. • 24-h recall was more likely to have more signficant food items reported, therefore making the most feasible method for piloting the UK national study of diet and low-income.	
Systematic Review					
(Vucic et al., 2009) low-income groups in Europe	To examine dietary intake methods to be used by researchers in order to screen or assess nutrient intake	• Multipass 24-h recall • FFQ • Semi-weighed method • Weighed food record • 5-7 day food record	• Four multipass 24-h recalls were shown to be the most appropriate method to study nutrition and health in low-income households, as it yielded higher estimates of energy and nutrient intake than the weighed food record. • Semi-weighed record was least preferred by both participant and interviewer due to survey fatigure.	• Low literacy skills, respondent biases, not accessible to participants, low motivation and barriers to cooking. • Living with a public kitchen made it challenging in assessing dietary intake.	• Physiclal disability interfered with weighing and recording. • Language and numeric skills influenced record methods like food diaries. • Mental health, dementia or drug and alcohol abuse can all hinder memory based methods.

24-h recall: 24-hour recall, DLW: Doubled labeled water; FFQ: Food Frequency Questionnaire

2.3.1 24-hour Recall

The 24-h recall captures an individual's food intake in chronological order (e.g., morning to night). It is designed to be culturally sensitive, cognitively easy, and therefore suitable for populations with low-literacy skills (Gibson et al., 2017). Moreover, this method is suitable for cohort studies, national surveys, and also used as a reference method to assess the validity of other dietary intake assessments (MRC, 2020). The advantage of this instrument is that it captures details about timing, location, source, brands, preparation, and cooking method of meals (Gibson et al., 2017). Sequentially, it helps assess energy and nutrient intakes, meal patterns, meal frequency, eating environments, and can compare an individual to group intakes.

Designing a 24-h recall should consider the potential measurement errors such as incorrect estimation of portion size, memory lapse, coding errors, and mistakes in handling mixed or takeaway meals. (Gibson, 2005). Following that, the time or day of the week, season, region, rural vs urban settings, sex, and age provides valuable context during data analysis (Gibson et al., 2017). For example, holidays often involve large gatherings and feasts that coincide with unusual eating patterns. Furthermore, a 24-h recall can be used in various ways depending on the aim of the research. A single dietary recall is sufficient to identify the average consumption of a large population. Multiple-pass 24-h recalls are recommended to identify population variation and the prevalence of individuals meeting specific intakes. More importantly, having them conducted on randomised days with standardised protocols can minimise respondent bias (Gibson et al., 2017). A 24-h recall can be conducted both electronically or in person coupled with using visual aids to assist with estimating portion sizes, such as food photographs, household measures, food models, and 2-dimensional grids (MRC, 2020). Additional studies have shown no difference between interviews conducted by telephone or face-to-face, despite using various ways to improve memory recall, such as training participants in portion sizes with geometric shapes, or sending them a food amount booklet with 2-dimensional food and measurement models. (Callender et al., 2017; Tran et al., 2000; Yanek et al., 2000). A trained interviewer that is knowledgeable of the local foods, culture of the ethnic groups, and has good interpersonal communication skills are equally vital to ensure dietary data is as accurate and reliable as possible (DeBiasse et al., 2018; St George et al., 2016).

The key strengths of an interviewer administrated 24-h recall compared to other dietary assessments include: 1) having no restrictions on the number of food that can be recorded, whereas a 7-item or 110-item FFQ are quantity restricted; 2) no literacy skills required by participants; 3) culture is not a major barrier; 4) does not alter food intake patterns (MRC, 2020). However, the main limitations include observer bias, reliance on memory, being expensive to administer, a high burden on participants if multiple recalls are required, and time-consuming for researchers to code and analyse data (MRC, 2020). In general, this is a traditional and subjective method that heavily relies on self-reporting, hence objective methods like biomarkers have been used alongside self-reported dietary assessment instruments to circumvent the underlying limitation of measurement error (Kaaks, 1997).

2.3.2 Food Frequency Questionnaire

Food frequency questionnaires (FFQ) are designed to evaluate one's habitual intake by asking the frequency of which a food item or a food group has been consumed over a referenced period (MRC, 2020). The list of foods can vary from 20-200 depending on the focus of a specific group of foods or nutrients. Completion and length of time can impact its reliability and reproducibility

(MRC, 2020). The FFQ remains controversial on whether it can accurately estimate of true dietary intake and sensitive enough to detect diet-disease relationships (MRC, 2020).

Overall, the FFQ is a versatile and adaptable instrument. Researchers need to use or create the most suitable FFQ format to best capture the data. An NZ study (n = 100) developed and validated four brief, self-administrated FFQs to measure the daily intake of F/V in multi-ethnic adults aged 25-60 years. (Mainvil et al., 2011). The four FFQs included: Two 5-item FFQ categorised into F/V intake; 12-item fruit FFQ; and 15-item vegetable FFQ listed the most commonly eaten F/V in NZ as shown in Table 2.6. These were all validated against a dietary history that asks the participant to summarise their eating pattern over the previous months, and describe up to 3 commonly consumed meals.

Table 2.6 *The fruit and vegetable listed in Mainvil et al. (2011) four brief, self-administrated FFQ*

5-item fruit FFQ	5 item-vegetable FFQ	12-item fruit FFQ	15-item vegetable FFQ
Juice, dried, cooked/canned/frozen, raw summer, other raw	Juice, raw, hot chips/wedges, cooked frequency, cooked portion sizes (photos of “1” serving supplied)	Bananas, apples, oranges, stone fruits (peaches, nectarines, plums, apricots), pears, berries, kiwifruit, grape, fruit juice, canned fruit, dried fruit and other fruit	Potatoes, carrots, tomatoes, lettuce, onions/leeks, peas, cabbage, cauliflower, broccoli, pumpkin, hot chips, green beans, tomato-based sauce, silverbeet/spinach/puha, and other vegetables

The 5-fruit item FFQ and 15-item vegetable FFQ were best matched with diet history, thereby best at identifying whether an individual’s usual F/V intake over the past month meets the daily recommended servings of F/V. Manvil et al. (2011) suggest these brief FFQ’s have potential use in NZ public health settings as a quick and cost-effective screening tool to assess individual and group F/V goal attainment (5+plus servings per day). Regardless, brief measures cannot provide precise feedback (e.g., you usually eat 1.2 servings of fruit per day) to participants on their F/V intake behaviours (Mainvil et al., 2011; MRC, 2020).

However, some researchers have a narrower aim and requires brief tools that are easy to administer and process, whilst able to adequately achieve the aim of the study (Subar et al., 2007; Thompson et al., 2000). Hence various dietary assessment tools are often used in conjunction with others to examine both food intake and the tool's validity as shown in Table 2.7.

Acceptability is another aspect studies have investigated. Tooze et al. (2007) used a combination of a 24-h recall, FFQ, picture sorted FFQ and meal pattern FFQ in low-literacy elderly with LSES living in rural North Carolina. They found that underreporting was not only associated with body mass index (BMI), but all four methods had high rates of low-energy reporting due to poor recall related to old age and low education attainment. Another feasibility study showed that a 24-h recall and 110-item FFQ used in women living in Boston public housing were acceptable in measuring dietary intake (DeBiasse et al., 2018). They reported 81 percent respondent rate from completing all dietary assessments, and received positive feedback from participant interviews (n = 26) regarding the acceptability of each dietary assessment (DeBiasse et al., 2018). Positive feedback on the 24-h recall included formatting, timing, or the ability to reflect on their intake, and more reflective of their true daily intake rather than over a year with the FFQ. These results are insightful to develop user-friendly dietary assessment tools.

Table 2.7 *Description of study outcomes on testing a 24-h recall with other dietary intake instruments to measure food intake in various populations*

Authors	Population	Intake measure	Dietary Assessment	Results	Other findings
Cross-sectional studies					
(Tooze et al., 2007)	Community dwelling elderly with a LSES and low literacy skills (n=94)	Energy intake	• 24-h recall • Modified block FFQ • Picture Sort FFQ • Meal Pattern FFQ	• Low energy reporting on all four dietary assessment tools. • Male low energy reporters were 60% for FFQ, 43% for 24-h recall, 37% for picture sorted FFQ, and 32% for meal pattern FFQ (32%). • Women had a lower energy report on the 24h recall (40%), followed by FFQ (38%). • BMI (p <0.01) and gender (p = 0.01) were significant, with males and higher BMI more likely to be low energy reporters.	• Elderly has memory difficulty. • This study was only designed for rural elderly with a LSES. • The majority of households had an annual income below $10,000 USD. • Reporting status did not significantly differ by ethnicity, age, education, household income and self-rated health.
(Lins et al., 2016)	Low-income, socially vulnerable mothers in Brazil (n=67)	Energy intake	• 24-h recall • FFQ • Double labeled water	• High misreporting in both methods; highest in FFQ. • Mean energy intake was significantly lower in 24-h recall versus FFQ, 1848.6kcal and 2,084.5kcal, respectively. • Body fat percentage and underreporting in FFQ (r = 0.245; p = 0.046) were correlated.	• Did not consider seasonal variability. • Unable to detect covariates and misreporting. • FFQ was more accurate than 24-h recall but has less precision.
(St George et al., 2016)	African American Youth (n=456)	Energy, fat, F/V intake	• Automated self-administrated 24-h recall • Interviewer administrated • 24-h recall	• Three random 24-h recall had a low reliability of ≥ 62%. To achieve a reliability of > 80%, there will need to be 8 recalls for energy intake, 21-32 recalls for fruits and 21-25 recalls for vegetables.	• Data collector were Caucasian, thus not culturally the same as the participants. • Portion size booklet and food models were used. • Female youths were more likely to underreport.
(Hartmann et al., 2018)	Low-income Brazilian undergraduate students (n=173)	F/V intake	• Three 24-h recalls	• Average F/V consumption was 145g/day and 61g/day, respectively. Fruits were usually eaten as a snack. • Group 1 (low-income assisted students) had a medium F/V intake of 370g on Day 3 vs	• More days would verify a more accurate picture of FV consumption • School café served pre-portioned fruit and did not allow students to take spares home, but vegetables were

Authors	Population	Intake measure	Dietary Assessment	Results	Other findings
				Group 2 (non-assisted students) in all quartiles (p = 0.001) with a medium F/V intake of 173g. • In all quartiles, Group 1 consumed more F/V than Group 2 (p = 0.001).	served freely. Daily menu at school varied. • F/V preparation in Brazil involves food hygiene & safety practices which hinder students eating F/V.
(Gregorič et al., 2019)	Elderly living in Slovenian residential homes (n=49)	Energy intake	• Web-based • 24-h recall • WFR • Food diaries	• WFR was lower than recommended values for energy & water intake. 24-recall underestimated 66% of dietary parameters compared to WFR. The ratio between the two methods for energy and retinol is 0.86 (r = 0.39, p = 0.005) and 1.00 (r = 0.61, p <0.001), respectively. • Web-based 24-h recall is a valid tool for a quick and simple assessment of the elderly.	• A picture book was provided to help with portion size estimation. • BMI cut-off values for overweight and obese is still unclear for older adults. • Cognitive function of older adults must be considered.
Validation studies					
(Thompson et al., 2000)	50-69yr old in 6 different states in America (n=436)	F/V intake	• Standard 7-item FFQ • Adapted 16-item FFQ • 24-h recall	• For men, the medium estimated true intake from 24-h recall was 6.5 servings, 16-item FFQ estimated 6.3 serving and the standard FFQ estimated 4.4 servings. • For women, the medium estimated true intake from 24-h recall was 5.7 servings, the 16-item FFQ estimated 6.0 servings and the standard FFQ estimated 5.0 servings.	• Potato chips and preserves were counted towards F/V. • The instrument should be different for different populations, with more clear and concise language. • F/V were under-estimated in both FFQ, but the 16-item FFQ was more accurate in estimating true intake.
(Kirkpatrick et al., 2019)	Low-income women in Washington, DC (n=302)	Energy, nutrient and food group intake	• Automated self-administrated • 24-h call • Interviewer administrated 24-h recall • WFR	• Group 1 reported 72% of items vs group 2 reported 74% of items (p = 0.56). • 38% of F/V were excluded in group 1 likely due to instrumental error vs. 36% in group 2 likely due to language barrier. • Vitamin A mean true value was 733ug, and based on 24-h recall, Group 1 was 660ug vs. group 2 was 731ug.	• Additional ingredients were often excluded: cucumbers, cheese, tomatoes mixed in with salad or sandwich. • Accuracy was lowest in lunch due to many additional ingredients in mixed dishes, despite having the same menu as pilot study.

FFQ: Food frequency questionnaire; WFR: weighed food record; True value measured by weighing the food

2.3.3 Dietary intake assessments limitation

Dietary intake assessments have limitations, such as misreporting being the most common reason (Poslusna et al., 2009). Gibson (2005) describes misreporting will always exist regardless of the type of dietary assessment method used. For example, mixed dishes like vegetable soup or lasagne can be difficult to recall and estimate (Kirkpatrick et al., 2019). Researchers have found under-reporting varies across different personal characteristics and food. For example, subjects may under-report "unhealthy foods" (e.g. cakes, biscuits, desserts, fats) or over-report healthy foods to impress others or avoid criticism (O'Loughlin et al., 2013). Under-reporting of energy is common among those with a higher BMI, LSES, females, lower level of education, psychological factors (stress, depression) and memory lapse (Livingstone et al., 2003; Poslusna et al., 2009). In a systematic review, Poslusna et al. (2009) found the mean percentage of energy-intake underreporting on a 24-h recall was 18-21% (median 19) in men and 4-40% in women (median 28). Whereas O'Loughlin et al. (2013) report that self-reported energy intake from a 1-day food diary decreased true intake by 20-47% compared with a wearable camera. The same study suggested using both instruments can provide more accurate estimation of energy intake.

Reasons for under-reporting can include participant's bias, social desirability and memory lapse (Gemming et al., 2014). These are unavoidable factors and it is important to use methods to reduce the prevalence of underreporting. For example, hiring interviewers from the same cultural or community group, training interviewers and providing participants with memory aid such as plastic food models, coloured paintings, houseware and photographs to help quantify portions. (Poslusna et al., 2009). Measurement errors in dietary assessment instruments can have consequences when interpreting data, like micronutrients. Such errors can hamper dietary data that are necessary for developing dietary guidelines (1994). Some researchers decided to exclude under-reporters to address the problem (Poslusna et al., 2009). Nonetheless, relying on memory and self-report remains the most prominent issue when conducting a large-scale nutrition survey. Hence, the use of technological instruments is growing to objectively assess food intake to overcome the limitations of traditional dietary assessment methods (Lorenzoni et al., 2019).

Technology has enabled real-time recording of dietary intake, for example, using a wearable camera, which can provide an opportunity to capture true intake with greater precision and accuracy (O'Loughlin et al., 2013). Smartphone advancements offer a more convenient, low cost and quick-to-use dietary instrument. Smartphone applications and computer software can capture food images and estimate portion size to reduce recall bias and misreporting. However, mobile phone-based methods still require some level of technological competence and literacy. The burden of using smartphones in LSES populations is reminding participants to take photos of their food (Jobarteh et al., 2020). Other technological tools use body acoustic motions to capture energy intake and eating behaviours, such as an ad hoc microphone that records chewing and swallowing movements (Bi et al., 2016), or a Bite-Counter bracelet that captures wrist movements while eating (Lorenzoni et al., 2019). However, limited studies have tested the feasibility of wearable food intake monitors in LSES population. Innovative instruments are being developed, but nutritional biomarkers can provide a more objective method to evaluate measurement errors in FFQ or 24-h recall.

2.4. Carotenoids

The role of vitamin A in the human body includes vision, immunity, regulation of cell growth and normal reproduction (National Institutes of Health 2022). Vitamin A is a fat-soluble vitamin found in two primary forms, retinol (animal sources) and carotenoids (mostly plant sources). Carotenoids, including β-carotene, α-carotene, lycopene, lutein and xanthophylls, are the organic yellow and orange-coloured pigments found in various F/V and animal products. They act as vitamin A precursors and antioxidants in the human body that protective against the harmful effect of free radicals, such as macular (eye) degeneration, skin damage from ultra-violet radiation, cardiovascular disease and some cancers (Eggersdorfer et al., 2018). Carotenoids must be obtained through dietary sources because the body cannot synthesise them; therefore, plasma concentrations of carotenoids can be reflective of F/V intake due to its high abundance in foods (Burrows et al., 2015).

Plasma carotenoid concentrations are widely used to validate or “calibrate” other error prone instruments because a biomarker is independent of those of self-reported intake (MRC, 2020; Radtke et al., 2020; Rahiman, 2013). Biomarkers sensitivity to intake are generally low and only have the capacity to detect extremities like very low or very high intakes (Gibson, 2005). At the same time, F/V varies in carotenoid composition, making the selection of a single carotenoid difficult (Burrows et al., 2015). A study conducted on Californian men were fed a low-carotenoid diet, and results showed plasma carotenoid declined on day 2-3 and day 14-15 (Rock et al., 1992). Plasma depletion half-life seemed to be less than 12 days for β-carotene, α-carotene and cryptoxanthin, and up to 33 days for lycopene (Rock et al., 1992). Overall, assessing plasma carotenoids is more suitable for examining short term intake as it provides a snapshot in time. Collecting multiple bloodwork for a long period can be invasive to the participant, expensive to test and store (Gibson, 2005), thereby more research is using a less invasive method to determine F/V status by measuring skin carotenoids status.

2.4.1 Skin Carotenoid measurements

There are two primary detections of carotenoid concentration in the human body, plasma and dermal carotenoid. As mentioned earlier, carotenoids are fat soluble and are carried in the blood by low-density lipoprotein (LDL), which can be detected in plasma. Dermal carotenoids are found in the stratum corneum cell, which acts as a protective barrier to external pollutants and provides antioxidant and photo-protective benefits to the skin.

There are two main pathways for the depositing of carotenoids in the skin after food ingestion, diffusion from adipose tissue and blood flow or through sweat glands onto the skin (Darvin et al., 2011). The deposit location makes it easy to identify and is visible through optical spectroscopy (Radtke et al., 2020). Increased plasma carotenoid concentrations also increase the concentration in all organs, including the skin. For example, studies have persistently shown that skin carotenoids are strongly associated with plasma carotenoids (Jahns et al., 2019; Jilcott Pitts et al., 2018). Conversely, biomarkers can be affected by metabolism, age, sex and lifestyle factors (e.g. smoking & exercise), thus absolute daily intake cannot be determine (MRC, 2020). Nevertheless, skin carotenoid status (SCS) is assessed by various spectroscopy technologies such as Resonance Raman spectroscopy (RRS) and pressure-mediated reflection spectroscopy (RS) like the Veggie Meter © (Longevity Link Corp, Salt Lake City, Utah, USA) (Radtke et al., 2020). A study conducted on middle-aged American women showed dietary carotenoids were weakly correlated with Resonance Raman Spectroscopy (RRS) ($r = 0.29$; $p = 0.034$) (Jahns et al., 2019). Another study conducted in Hispanic low-income adults showed every 100 units of VM© corresponded with 1-cup of self-reported F/V, however the scores do not describe what type or colour of the F/V as there are different types of carotenoids across all F/V. While the association between F/V intake and skin carotenoid concentration remains controversial as shown from current literature in Table 2.8, the use of a biomarker can provide evidence of accuracy and calibration for other subjective dietary assessment tools (Kaaks, 1997).

Table 2.8 *Studies using both spectroscopy and self-report F/V tool to measure F/V intake*

Authors	Population	Dietary Assessments	The association between skin carotenoid and F/V	Other important findings
Cross-sectional studies				
Di Nola & Gellermann, 2021	Low-income Hispanic adults living in urban area of New Jersey, USA (n=132)	• NCI F/V screen Veggie Meter	• Mean RS score was 270 ± 65 (range 0-695; zero being no detectable carotenoid absorption). • Participants consumed >3 servings F/V had a RS score of 282 ± 105 vs. <3 servings F/V had a RS 253 ± 82. • Every 100 units of VM score corresponded with 1 cup of self-reported F/V (1 cup = fist size).	• Breastfeeding mothers had high F/V intakes than non-breastfeeding mothers. • 73% of participant had a BMI>25 and RS score was negatively associated with BMI (r=-0.22, p<0.001). • Mean RS scores in non smokers (272 ± 96) vs. smokers (208 ± 67).
Seguin-Fowler et al., 2021	Children aged 2-12 years living in low-income household, USA (n=177)	• RRS • 24-h recall • NCI F/V screener	• On average, children consumed 2.7- 3.7 cups of F/V per day, depending on which assessment tool used. • 24-h recall was positively correlated with RRS (p <0.01), but NCI F/V screener was not associated with skin carotenoid. • RRS score at 2 cups F/V approxmiated 36,000 units vs. 4 cups F/V at 40,000 units.	• Dietary fat intake was associated with skin carotenoid (p <0.05), but not BMI and energy intake. • Unknown if children absorb or metabolises carotenoid at different development stages.
Fultz et al., 2021	Low-income ≥ 60 years adults participating in the commodity supplement program in the USA (n=154)	• Food Behaviour Checklist • Veggie Meter	• On average, participants reported having 2.5±1.2 cups of F/V per day. • The association between VM and F/V intake was statistically significant in females (r = 0.202, p = 0.039) but not in males. • Mean VM score was 172.3±77.2, whilst significantly different by sex (male VM score 165 vs. female 176) and race (non-white VM score of 188 vs. white 142).	• 67% of participant are at risk of food insecurity with a mean age of 71 years. • VM score did not significantly differ with food security status (p = 0.117). • More research needed to validate VM in older, ethnic minority populations with varying skin colour and ageing skin.
Hill, Paschall, O'Brien, &	Alaska Yup'ik Native Community	• Two 24-h recalls • Veggie Meter	• Medium intake of F/V was 2.5 servings per day, and mean VM score was 220 ± 108.	• Only 17%, 47% and 29% of subjects reported eating brightly coloured fruits, deep-yellow vegetables and dark-green vegetables, respectively.

Authors	Population	Dietary Assessments	The association between skin carotenoid and F/V	Other important findings
Bersamin, 2021	(n=80)		• Skin carotenoid status was not significantly correlated with self-reported F/V (r = 0.15, p = 0.19). • VM score was higher in male than female (262 vs 185, p = 0.002). • RS were significanlty higher in those who ate more than 1 serving of F/V (232 vs.180, p = 0.02).	• Underreporting and overreporting habits between females and males can cause data inconsistency. • Carotenoid from fish did not influence SCS. • F/V accessibility is very limited in remote Alaska and all participants had the same nutrition exposure regardless of income and education.
Martinelli et al., 2021	4^{th}-6^{th} grader, aged 9-11 yrs. in Phoenix Arizona elementary school (n=143)	• Veggie Meter • F/V • SPAN Questionnaire	• VM score ranged from 34-447, with a mean of 210 ±72 for all students. • High income students had lower mean VM scores 201±80 than low-income students 221 ±59 (p = 0.044). • A weak association between VM values and self-reported total vegetable intake (r = 0.174, p = 0.042). • No correlation between VM values with self-reported total orange and green vegetable intake (r = 0.113, p = 0.185) and total fruit (r = 0.048, p = 0.571).	• First few studies to use VM to objectively measure F/V intake in children. • Did not account of adiposity or use of vitamin supplements. • A smaller sample size in low-income student hence resulted in higher VM score than high-income students.
(Rush et al., 2020)	Aged ≥ 16 years in New Zealand (n=571)	• 6-item FFQ • Veggie Meter	• Pacific had the lowest VM score than all ethnic groups 257±85, whilst Asian had the highest 388±115. Māori 351±110 and European 352±111 had similar CRS. • Women consumed 3.0±1.6 servings of vegetable and 2.2±1.4 servings of fruit per day. • One serving of dark green leafy vegetables a week added 6.7 units. One serving of carrots or pumpkin a week added 9.4 units.	• Older participants (>40yrs) had higher CRS than younger participant by 21 units (p = 0.033). • Smokers were 72 units higher than non-smokers (95% CI 34, 110) (p >0.001). • Increase of BMI associated with a reduction in VM score of 5.4 units. • 39.4% of participant consumed both 3+ servings of vegetable and 2+servings of fruits per day.

Authors	Population	Dietary Assessments	The association between skin carotenoid and F/V	Other important findings
				• 53.3% of participant reported consuming 3 or more servings of vegetables/day, and 61.6% reported 2 or more servings of fruit/day.
Jahns et al., 2019	40-60 yr. old women in North Dakota (n=52)	• RRS & RS • Thirty-six automated 24-h recall • Plasma carotenoid	• Skin carotenoid is strongly associated with plasma carotenoid at baseline • (*r* = 0.70; *p* <0.001) and across the year (*r* = 0.65, *p* <0.001). • Self-reported F/V was weakly associated with both RRS and RS (*r* = 0.37, *p* <0.01). • No difference during seasons in self-reported F/V (*p* = 0.441) and carotenoid intake (*p* = 0.983).	• Participants were overweight, 23% being obese. • Self-report food intake was the only way to assess dietary pattern.
Pezdirc et al., 2015	18-30 year old Caucasian women in Australia (=91)	• 120-item FFQ (Australian Eating Survey 2010) • Spectrophotometer	• Higher F/V intake is associated with higher skin yellowness (*β* = 1.0, *p* = 0.004). Lutein/zeaxanthin was significantly associated with overall skin yellowness (*β* = 0.03, *p* = 0.010) • Dietary intake of beta-carotenoid (*r* = -0.69, *p* <0.001) and lycopene (*r* = 0.82, *p* <0.001) were significant with their respective absorption spectra.	• Only 16.5% of women met the Australian recommendations of 2 servings of fruits and 5 servings of vegetables. • FFQ did not ask how the food was cooked as it can highly influence bioavailability of carotenoids. • First study to explore dietary lutein/zeaxanthin and skin colour.
Scarmo et al., 2012	3-5 year old pre-school economically disadvantaged children in Connecticut USA (n=381)	• 41-item FFQ – 1 week intake (English & Spanish) • RRS	• White-non-Hispanics had the highest skin carotenoid status RRS of 24 (*p* = 0.08), but no difference between skin pigmentation. • F/V intake were positively associated with RRS (*r* partial = 0.17). • RRS was significantly lower in children who are participating in a nutrition assisted program compared to those who are not (19.3 vs 21.8, *p* <0.01).	• Parent/ guardian of child did the 1-week food assessment, whereas skin tissue reflects weeks to month of F/V intake. • Almost 1/3 of participants were overweight/ obese, which was inversely associated with skin carotenoid status.
Validation study				
(Jilcott Pitts et al., 2018)	African American and	• RS	• Mean F/V was 0.48 servings per day (*p* = 0.009).	• RS device was a feasible and reliable assessment tool for measuring skin

Authors	Population	Dietary Assessments	The association between skin carotenoid and F/V	Other important findings
	Non-Hispanic White in North Carolina (n=30)	• FHCRC 125-item FFQ • Plasma carotenoid	• Mean total carotenoid intake from food was 0.69ug/day. • Significant correlations between RS, FFQ, plasma carotenoid, except for FFQ and RS amongst African American (*r* = 0.12, *p* = 0.635).	carotenoid status in racial diverse groups. • Nicotine and chilli powder on potato chips can stain the skin and potentially effect RS reflection.

BMI: Body mass index; CRS: Carotenoid reflection status; NCI: National Cancer Institute; FFQ: Food frequency questionnaire; F/V: fruit and vegetables; FHCRC: Fred Hutchinson Cancer Research Centre; RRS: Resonance Raman Spectroscopy; RS: Reflection spectroscopy; VM: Veggie Meter

2.4.2 Spectroscopy

Spectroscopy is a rapid, objective and invasive method using absorption and emission of light to identify the bioactive carotenoids, including lycopene, lutein, α-γ-βeta-carotene and zeaxanthin (Stahl et al., 2005) found in skin to measure F/V intake (Radtke et al., 2020). Resonance Raman Spectroscopy (RRS) and pressure-mediated reflection spectroscopy (RS) can quickly screen for skin carotenoid status. They have shown great application in large-scale F/V intervention studies investigating the correlations between F/V intake and health and disease outcomes (Ermakov et al., 2018).

How spectroscopy works

RS operates similarly to RRS but is more portable, affordable, readily available, and accessible (Martinelli et al., 2021). RS works by using a broadband light source of 400-500nm to measure the pigment and density of dermal carotenoids (Rahiman, 2013). The spring-loaded cover applies pressure to the skin's location and temporarily restricts blood flow to minimise other co-founding bioactive compounds (e.g., scattering blood and melanin) in the background. This will reduce the interference to better identity carotenoid compounds (Ermakov & Gellermann, 2012). Moreover, this makes the RS method an advantage as it computes all chromophores (a molecule responsible for colour) in the skin and takes them into account in deriving a skin carotenoid score (Ermakov et al., 2018). While applying white LED light and pressure, residual de-oxy haemoglobin levels combined with skin melanin, and intrinsic tissue scattering are quantified with a spectral deconvolution algorithm. This calculates the skin carotenoid absorption strength and generates the optical density units afterwards (Ermakov et al., 2018). The optical density units directly correlate with carotenoid concentration in the measured tissue volume.

Veggie Meter

The Veggie Meter© (VM©) is an RS-operated tool that works by emitting a light source to measure the density and colour of dermal carotenoid on the fingertip to generate a Carotenoid Reflection Score (CRS) (Ermakov et al., 2012; Rush et al., 2020). The inner palm was found to have the highest concentration and the most reliable skin site to assess carotenoid levels due to a higher lipid/protein ratio and minimal pigmentation (Ermakov et al., 2012). However, Rush et al. (2020) reported that skin carotenoid determinants such as a BMI > 25.0 kg/m^2 is found to have a negative correlation with CRS. The inverse relationship between BMI and carotenoid concentration has three plausible reasons: 1) both can be largely affected by dietary and lifestyle factors; 2) since carotenoid is fat-soluble, the distribution in adipose tissue increases thereby decreasing serum concentrations; 3) adipose tissue may undergo oxidative stress, thereby reducing skin carotenoids levels. Other factors such as the common cold and smoking were also found to decrease dermal carotenoid concentration (Darvin et al., 2011). A British study found that long-term non-smokers and obese (> 30kg/m^2) young adults had a 24-37% lower carotenoid (lycopene) concentration than those with BMI < 22kg/m^2 (Andersen et al., 2006). This is due to the direct effects of tobacco-induced oxidation of carotenoids that decrease body uptake of carotenoids (Di Noia et al., 2021). One study found that nicotine and coating of chilli powder from chips or processed foods temporarily stain the skin, even after washing hands and cleaning with alcohol wipes (Whigham et al., 2016). This introduces a non-systematic error to data. On the other hand, there is still a lack of studies on older adults and factors like ageing skin, which can affect the accuracy of spectroscopy (Radtke et al., 2020). In summary, many external factors can affect carotenoid concentration that can influence the overall results when determining F/V intake (Table 2.8).

2.4.3 Comparing F/V intake in Skin Carotenoid and 24-hour Food Recall

Spectroscopy can be a quick and non-invasive alternative method to objectively measure F/V intake. It also helps decrease the likelihood of bias and reliance on nutrient profile databases (Radtke et al., 2020). However, using a comprehensive and subjective dietary measure can be beneficial in identifying sources of carotenoids and provide context around RS scores that RS cannot provide. For example, information on how F/V was stored and cooked or types of foods consumed from 24-h recalls are valuable as it affects carotenoid content (Jahns et al., 2019). The overall evidence for the correlation between skin carotenoid status and F/V intake remains undetermined regardless if it was FFQ, NCI F/V screener or 24-h recall (Table 2.6). On the other hand, the Radtke systematic review (2020) showed that spectroscopy and dietary intakes were significantly associated with skin carotenoids and F/V intake (Beccarelli et al., 2017; Scarmo et al., 2012). It is not to say that there is no correlation, but it may underpin the inaccuracy or inappropriateness of the subjective dietary intake instrument used in the study. In summary, measuring and evaluating F/V intake requires subjective and objective measures to optimise the relationship between nutrition and health outcomes.

Chapter 3 – Research Manuscript

Abstract

Background: High fruit and vegetables (F/V) intake have been shown to decrease risk of non-communicable diseases. Māori people living in deprived areas are exposed to a greater nutritional risk due to a lower F/V intake, and there are no validated instruments to measure F/V intake in this population.

Aim: To assess the feasibility of a 24-hour (24-h) recall versus skin carotenoids to assess F/V intake in low-income Māori households participating in a F/V intervention study.

Methods: This feasibility study was conducted in 12 Māori households in Palmerston North, New Zealand. Intake of F/V were measured by a 24-h recall and skin carotenoid via Veggie Meter © (VM) on four randomised days during baseline and intervention, separated by a five week washout period. Participants received a weekly free box of F/V during intervention. Feasibility of both instruments were analysed by Pearson and Spearman correlation. Significance was set as $p < 0.05$.

Results: There was no significant difference in the mean total F/V servings across the study. Median servings and intake of fruit were significantly different between baseline and endpoint ($p = 0.05$). Only one (8%) participant met the recommendations of 5 servings of vegetables and 2 servings of fruits at baseline, and four participants (50%) at endpoint. Spearman's rho correlation showed no association between VM scores and self-reported F/V intake ($p = 0.50$). A significant correlation was found between those with a ≥250 VM score and intake of yellow-vitamin-A F/V and F/V at baseline ($p = 0.04$) and intervention ($p = 0.03$).

Conclusion: The developed 24-h recall was a feasible tool to assess F/V intake in low-income Māori groups. Measuring skin carotenoids may be a more feasible method to measure vitamin A intake rather than F/V.

3.1 Introduction

Rates of obesity and non-communicable diseases are rising nationally and globally (Ministry of Health 2020). For example, obesity rates amongst women in New Zealand (NZ) have risen by 4% from 2019/20 to 2020/21. Adults and children living in socioeconomically deprived areas are 1.6 and 2.5 times more likely to be obese than in non-deprived areas, respectively (Ministry of Health 2021b). In November 2020, the Ministry of Health (MoH) updated its Eating and Activity Guidelines for NZ Adults to reflect the current health landscape. Daily serving sizes increased from three to five servings of vegetables (75g each), and fruit remained the same at two servings (150g each). Just less than half (30%) of people in NZ and 28% for Māori people living in NZ have met the MoH guidelines (Ministry of Health 2020).

High intake of fruit and vegetables (F/V) has persistently shown to lower the risk of developing obesity and non-communicable diseases (Ezzati et al., 2002; Health, 2003; Ministry of Health, 2003; Rush et al., 2019). Many dietary guidelines recommend higher intakes of F/V due to its high abundance of vitamins, minerals and fibre. Orange and yellow-coloured F/V are rich in carotenoids (a form of vitamin A) and hence placed in a separate category (Slavin et al., 2012). Fruit and potatoes are nutritious, but when processed into sweetened tropical juice or French fries, they can be energy dense and low in fibre, so caution should be used when interpreting F/V intake (National Health and Medical Council, 2013).

Whilst F/V are highly promoted for its health benefits, barriers to eating healthy are multifactorial. Māori households living in deprived areas often experience inequitable food shortages due to the impact of colonisation (Moeke-Pickering et al., 2015), therefore placing them at a higher nutritional risk. In order to measure F/V intake in this population, an acceptable and validated dietary assessment tool is needed to accurately collect reliable data to improve access to healthy kai (food) and Hauora (well-being) amongst Māori communities. Furthermore, studies on F/V intake and dietary assessment tools in Māori communities are currently limited in the literature. Skin carotenoid status (SCS) is an objective method to measure F/V intake, whilst subjective methods such as food frequency questionnaires (FFQ), 24-h recalls and food records are prone to poor recall, respondent bias, underreporting, overreporting energy intake (Vucic et al., 2009). These measurement errors can hamper data accuracy, which is necessary for developing health interventions and policies. Therefore, this study aimed to assess the feasibility of an adapted 24-h recall method versus skin carotenoid status via Veggie Meter© (VM) to measure F/V intake in low-income Māori households.

3.2 Methods

3.2.1 Study Design

3.2.1.1 Ethical consideration

This study has taken significant care to ensure it is ethically sound for this population. Respecting Māori beliefs and values is crucial to preserve Tino Rangatiratanga (self-determination and independence), especially when working in a low-income community (Krieger, 2001; Reid et al., 2007). Moreover, whānau should have a sense of control over the entire research process. Approaches to improve cultural appropriateness include acknowledging traditional food preparation methods, karakia, using Te Reo Māori, Mātaurange Māori (knowledge specific to Māori) and most importantly, speaking to the correct whānau member to increase engagement and ongoing contact. In order to conduct all dietary assessments, it was crucial to involve research assistants (RAs) from the Te Wakahuia Manawatū Trust since they have extensive knowledge and experience working with the community. Te Wakahuia Manawatū Trust is a Māori community health service based in Highbury, Palmerston North that was co-opted to support recruitment and data collection for the feasibility study.

3.3.1.2 Sub-study design

This was a sub-study of a larger HRC feasibility project grant 19/664 (He Pātaka Marohi) of novel and conventional instruments to measure F/V consumption among 15 Māori households during an intervention providing free fruit and vegetables. The target population mainly lived in Highbury, which is rated as a highly deprived neighbourhood in Palmerston North according to the 2018 NZ Index of Multiple Deprivation (University of Auckland 2018). In the broad feasibility study, two additional instruments were examined – questions from The Adult Health Survey New Zealand and smartphone photos. In addition, a supply surplus method (tracking FV consumption) during the intervention and a post-intervention interview regarding the acceptability and feasibility of the tools were included (refer to flow chart of study design figure 3.1). Participants in an earlier F/V Explorer study (HRC17/659) (Kira et al., 2021) were invited again by the Te Wakahuia Manawatū Trust to join this study. A total of 16 households were recruited at the start and the participants gave written informed consent (including awareness of the right to withdraw at any time and confidentiality of data) before data collection commenced. The study was a 12-week feasibility study conducted between December 2021 and February 2022 (summer season) in low-income Māori households living in Palmerston North, NZ.

This sub-study focused on developing a 24-h recall method alongside a training manual, protocol and resources for RAs to use to measure F/V intake specifically. Secondly, it examined the feasibility of conducting the developed 24-h recall by comparing with SCS via the Veggie Meter® (Longevity Link Corp, Salt Lake City, Utah, USA). Ethics was approved by Massey University Human Ethics Committee (Southern A, Application 21/37). The study's measurements were randomised on three weekdays and one on the weekend.

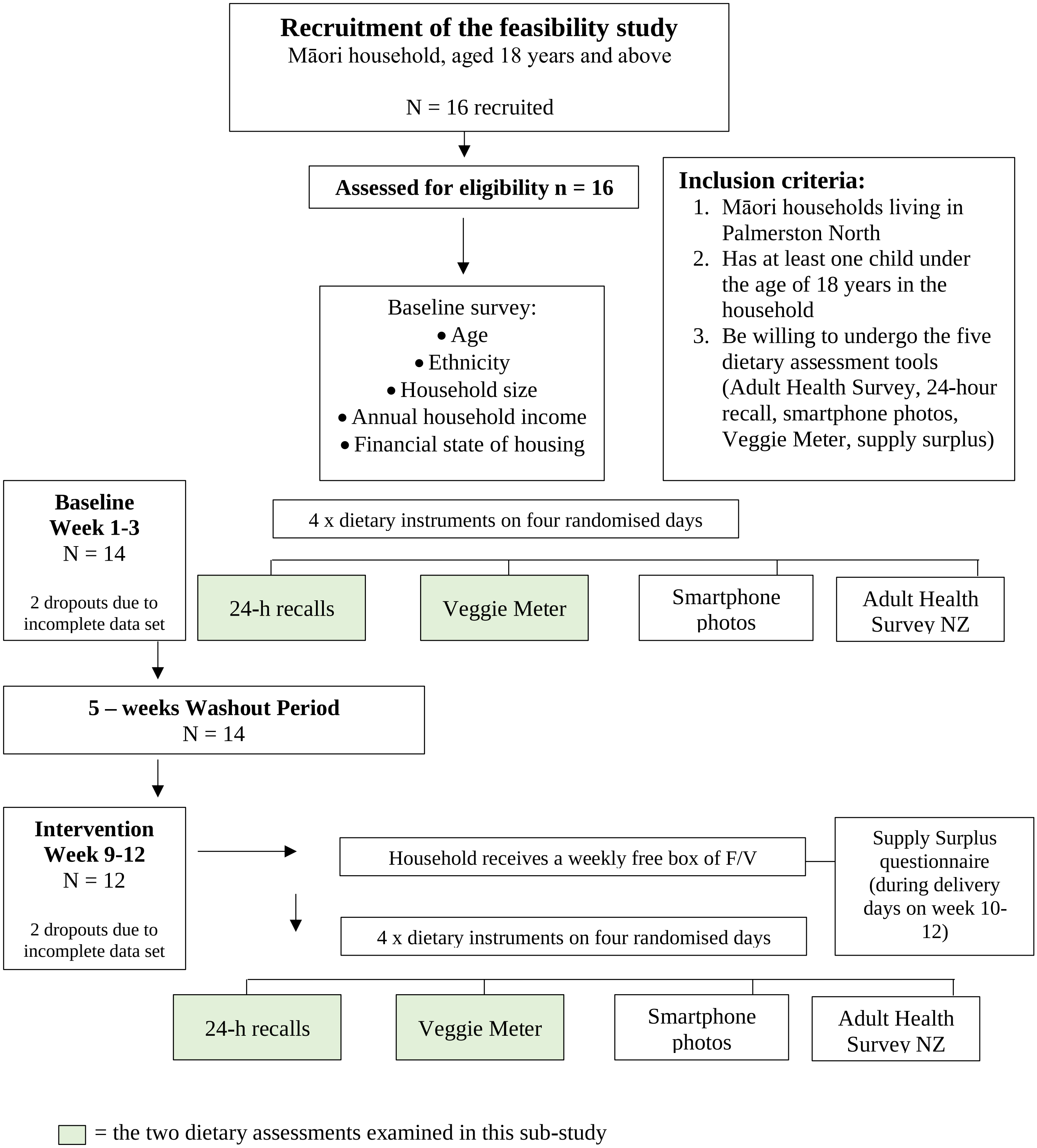


Figure 3.1 *Flow diagram of the feasibility study design*

3.2.3 Methodology developed for delivery of 24-h recall and staff training

In this sub-study, the tool-kit was developed by the student dietitian to include the 24-h recall template together with an interview script, a F/V diversity questionnaire, a portion size booklet, and a training manual with an associated dishware tool-kit. The entire tool-kit was used by the RAs throughout the study and will be discussed in the following sections.

3.2.3.1 Development of 24-h recall and F/V diversity

Misreporting of dietary intake is a common issue in dietary studies. The 24-h recall, script and resources (Appendix A) were created with the goal of minimising errors such as respondent bias, interviewer bias, memory lapse and incorrect estimation of portion sizes (Gibson & Ferguson, 1999). The adapted 24-h recall was developed using the Diet, Anthropometry and Physical Activity (DAPA) Measurement Toolkit's multiple-pass approach method. This method was invented in the USAD (United States Academics Decathlon) in 1999 (Raper et al., 2004), and it is now widely used in national surveys. Rather than chronological order, the multi-pass tactic is tailored to human cognition.

Step one

The "quick list" was added to allow participants to compile a list of foods and beverages consumed in the previous 24 hours without any interruption. This first step is conceptualised as a "mind dump" (refer to Table 3.1 & 3.2) and was inspired by Nelson and colleagues' format at King's College London (Subar et al., 2007). Cognitive research has revealed that people remember in different ways, and once recalling begins, it is best to allow people to continue the process uninterrupted and return to collect details later (Subar et al., 2007).

Step two

The RA then used probing questions to guide participants to recall more details from the quick list in chronological order. This process can trigger forgotten foods. The probing questions were inspired by Gibson and Ferguson (1999) 24-h recall manual. Specific descriptions from the manual were tailored to F/V intake, for example, “commercial vs homemade”, “peeled or unpeeled F/V”, “brand-name” and “condiments added”. Other sections of the 24-h recall (amounts, location, time, cooking method of foods consumed and a dinnerware code) were included to aid data entry (Appendix A, Table 1). These details can provide greater context on eating patterns and behaviours.

Step three

The last step was broken into three parts: 1) final probe, which explored any potential forgotten foods such as sauces, condiments, cooking methods and snacks by chronologically reviewing all the recorded items, 2) probed for feast days, usual intake and sickness (if sick, probe for appetite), and this format was again inspired by Gibson and Ferguson (1999) 24-h recall manual 3) summarised everything (Appendix A, Table 1).

Table 3.1 *The original 24-h recall template*

Time food was eaten	**Place eaten**	**Complete description of food** (preparation, variety, brand) If possible, attach the recipe or nutrition label (fortified foods)	**Amount consumed (units, measures, weight)**

Table 3.2 *The adapted multiple-pass 24-h recall template used in this study*

Quick List	**Time**	**Place Eaten**	**Description of food/drink** Include brands, sauces, oil, dressings, toppings, recipes	**Amount Eaten** (unit, measure, weight /volume)	**Dinner-ware**	**Cooking method**

F/V diversity questionnaire

Lastly, participants did a quick verbal F/V diversity questionnaire that asked whether they had consumed a particular F/V (yes/no) in the past 24 hours (Food and Agriculture Organization, 2013). The aim was to cross-check the information with self-reported F/V on the 24-h recall and to examine the diversity in their diet. A similar feasibility study highlighted the importance of modifying the FFQs' to capture cultural foods (DeBiasse et al., 2018), hence Māori Kai and Te Reo Māori have been incorporated (Appendix A, Table 2). The original FFQ used in the previous F/V study listed 30 different F/V (Kira et al., 2021), but seven additional F/V that are commonly eaten in Māori culture were added, including lettuce, mandarins, plums, watermelon, grapes, pineapple and tropical fruit juice.

3.2.3.2 Development of Portion Size Resources

The quantity and type of F/V consumed are the most critical data to collect, and estimating portion sizes remains the greatest threat in data accuracy. Many studies have used various methods to assist with quantifying portions, such as food models, portion size booklets, drawings, and photographs (Poslusna et al., 2009; St George et al., 2016). However, the existing plastic food models and photographs hardly contain NZ and Māori-specific kai (food). Henceforth, developing a portion size booklet and a dinnerware toolkit was more culturally appropriate to assist in data collection.

The portion size booklet has eight pages of photos to help with portion estimation (Appendix A, Figure 1). The first three pages featured everyday dishware from K-Mart and Warehouse online stores. Since many existing government-based resources used European hands, cartooned hand portions from the Nestlé Professional website were selected. The following pages compared food portions with familiar objects from the Healthy Food Guide resource, as well as various cuts of vegetables (e.g., julienne carrots, chunks and diced potatoes). The final page featured photographs of defining fist size vs handful. Furthermore, the dishware toolkit was assembled in the same way as the dishware photos in the booklet and was purchased from the same stores. Overall, the two resources were designed to be visual, tactile, and easy to follow.

3.2.3.3 Training Research Assistants

Two RAs were recruited internally from Te Whakahuia Manawatū Trust staff, one of whom has worked in this community for nine years and one for six months. Studies have highlighted that it would benefit if the data collectors knew the participants' food, environment, and language of the participants to reduce biases (Kruger et al., 2008; St George et al., 2016). Since this study involved a Māori population living in a low-income community; having RAs who are familiar with the participants will make them feel safe at home and be more willing to share their diet. In the two training sessions (one hour each), the student dietitian guided the RAs through the training manual and each resource (Appendix A, Figure 2); trained them to conduct a 24-h recall through role-playing, and provided direct feedback during practice. To minimize the risk of underreporting and overreporting of F/V, the RAs received two additional online training sessions (one hour each) on serving sizes with the student dietitian and research dietitian before the study commenced. RAs were given feedback on how to record portion sizes more accurately and how to problem solve certain obstacles via email and Zoom calls (due to Covid-19 restrictions).

3.2.4 Dietary Data

Trained RAs conducted the 24-h recall either at participants' homes or over the phone in accordance with Covid-19 protocols. Every 24-h recall was audio recorded and on average, it took 15-20 minute to complete. A portion size booklet and dishware toolkit were only provided during home visits to assist portion size estimation. Although participants had no access to the dishware toolkit over the telephone, the audio recordings showed that they were more knowledgeable about how to estimate portion sizes during intervention. The skin carotenoid measurements were taken at the participants' home on separate randomised days. The RAs followed the manufacturer's cleaning instructions and took three consecutive scores. Following a 5-week washout period, the participants received a weekly free box of F/V (including seven servings of F/V enough for each member in the household). The supplier (Pak'n Save, one of NZ's biggest supermarkets) was responsible for choosing which F/V goes into the box, and the research team collected the box each week and measured the weight of each F/V. The participants received ten types of FV, including potatoes, onions, carrots, kumara, sweet potato, broccoli, cabbage, apples, oranges and plums. The exact dietary assessment measurements from baseline were conducted again (Figure 3.1).

3.2.4.1 Data handling

Initial analysis was performed on Microsoft Excel, such as identifying F/V on recalls and translating the recorded quantity into grammes and serving sizes. Audio recordings were used to confirm each recall, and to clarify any misleading or incomplete information. The NZ Food Composition Concise Table 13th edition was used to determine the standard weight of F/V. If not found, such as "cooked watercress", the weight was either found on Google Search or the Australian Food Composition Database. Servings were defined as 75g of vegetables and 150g of fruit to comply with the new MoH Eating and Activity Guidelines (2020). To minimise overestimation, some vegetables such as onions, corn, and peeled potatoes were calculated by [total weight x edible portion percentage] (Appendix A, Table 4). Takeaways such as Tank smoothies, Burger King fries or Subway weights were found on the brand's website or roughly estimated based on images found online. Mixed foods such as banana bread, weight and percentages of F/V used in the recipe were found in similar products on Countdown's website. For example, ([% of F/V ÷ total weight] x amount eaten). All portion codes in the booklet have been calculated and estimated into quantities, for example, H2 (fist size) = 1 cup, or B2 (cereal bowl) = ~2.5 cup, or C2 (medium glass) = ~270mL. F/V were then categorised into food groups outlined in Appendix A Supplementary Table 5.

Potatoes, including deep-fried and air-fried chips were counted towards a vegetable serving. Excluded F/V servings were a packet of crisps, tomato sauce ("ketchup"), pre-packaged fruit juice, condiments, fruit-flavoured beverages, and avocados, as their high content of sugar, salt, or fat outweighs the health benefits. However, fruit juice and avocados were still analysed for general consumption. Potato chips was their own category to examine how much deep-fried potatoes were consumed vs roasted /boiled potatoes. Lastly, the average F/V intake (g) and serving sizes were calculated by the number of completed recalls and participants.

Each participant's VM scores were averaged from the three readings. Moreover, the F/V given in the box was recalculated into the average daily amount (g) and serving sizes per participant. Sweet potato was excluded from analysis as it is the same as kumara.

3.3.5 Statistical Analysis

Analyses were performed with Statistical Package for Social Sciences (SPSS) version 20 (SPSS Inc. Chicago, Illinois, U.S.A). Normality was tested using Shapiro-Wilk tests (>0.05), skewness and kurtosis, alongside with Normal Q-Q box and histograms. Categorical and ordinal variables such as ethnicity, household size, annual income, types of meals, frequency of FV diversity were reported as count and percentage (%). Normally distributed data (age, number of adults, children living in households, vegetable, and non-starchy vegetable intake) were reported as mean (±SD).

And non-normally distributed data such as fruit intake, food groups and Veggie Meter ® (VM) were presented as median with 25^{th} -75^{th} percentiles. Paired sample t-tests and Wilcoxon-signed rank test were used to compare pre and post intervention F/V consumption for normally distributed and non-normally distributed data, respectively. Participants (n = 12) who completed both baseline and end point assessment were included in the analysis. Pearson correlation (for normally distributed data) and Spearman correlation (for non-normally distributed data) were used to investigate the association between F/V intake and VM scores. As F/V intake can vary by demographics, descriptive tests were used to report mean and percentages.

Given skin carotenoid status can be influenced by smoking status, an independent t-test was used to examine if VM score differed by smoking status.

3.4 Results

3.4.1 Participants

Out of the 16 participants recruited and enrolled in the feasibility study, 14 completed the three week baseline, whilst only 12 completed the three week intervention, and thus the entire study. Two dropped out at baseline, and another two at intervention.

3.4.1.1 Demographic characteristics

Demographic characteristics of the study population are presented in Table 3.3. All 14 participants were females aged between 24-53 years, and eight (58%) were smokers. The average household were composed of two children and three adults, the majority did not know their household annual income and 36% were renting a home.

Table 3.3 *Participant baseline demographic and characteristics (n = 14)*

Characteristics	Category	n (%)	Mean ± SD
Age (years)		13	34 ± 9.6
Sex	Female	14 (100)	
Ethnicity	Māori	12 (85.7)	
	Pasifika	1 (7.1)	
	Māori/European	1 (7.1)	
Number of adults in household		14	2 ± 1.37
Number of children <18 years old		14	3 ± 1.97
Smoking status (n=14)	Smokers	9 (64.3)	
	Non-smokers	5 (35.7)	
Financial housing state (n=14)	Own with mortgage	3 (21.4)	
	Rent	6 (42.8)	
	State housing	4 (28.6)	
	Other	1 (7.1)	
Annual income of household (n=14)	<$50,000	1 (7.1)	
	≥50,000	2 (14.3)	
	Don't know / Don't want to answer	11 (78.6)	

There were two missing participant IDs but their demographic characteristics were included in this table. The one participant that identified as Pasifika had dual ethnicity with Māori. There was one missing data for age. Age was collected as birth year and subtracted by the Year 2021 (when the participant enrolled in the study).

3.4.2 Total Fruit and Vegetable intake

The total F/V servings increased from 5.1 ± 2.4 to 6.5 ± 2.7 over the study period ($p = 0.065$), and the total F/V intake has increased by 123 ± 237g/d. Total F/V intake is shown in Figure 3.2. One (8%) participant met the MoH daily recommendations of 5 servings of vegetables and 2 servings of fruits at baseline, and four participants (50%) at endpoint (Figure 3.3). Six (50%) participants increased their daily F/V by 0.5-2.0 servings, and three (25%) increased by ≥3 servings. All the yellow-coloured and vitamin-A rich F/V were combined, and results revealed a significant increase from 0.5 (0.3-1.5) servings at baseline to 2.0 (0.6-2.6) servings at endpoint (p = 0.002). (Data are not shown in table).

Among the demographic characteristics, the one household with four children increased their daily F/V from 3.0 to 8.2 servings. Those with two and five children in the household both increased their daily F/V by 2.2 servings. Those living in state housing increased their daily F/V by 1.3 servings. Smokers and non-smokers had similar F/V servings at baseline, but increased during intervention by 1.8 servings in non-smokers (p = 0.27), and significantly increased by 2.2 servings in smokers (p = 0.02). (Data are not shown in tables or graphs).

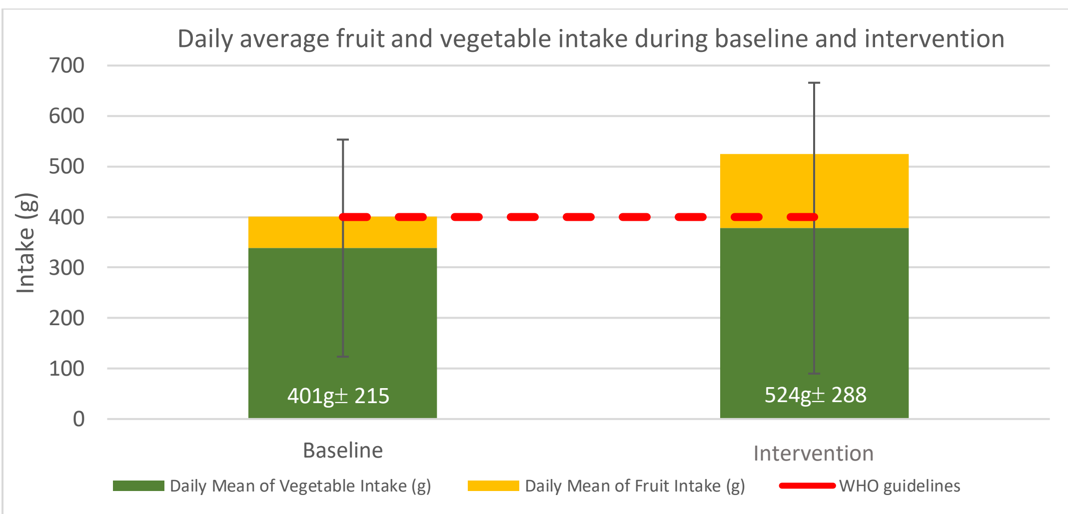
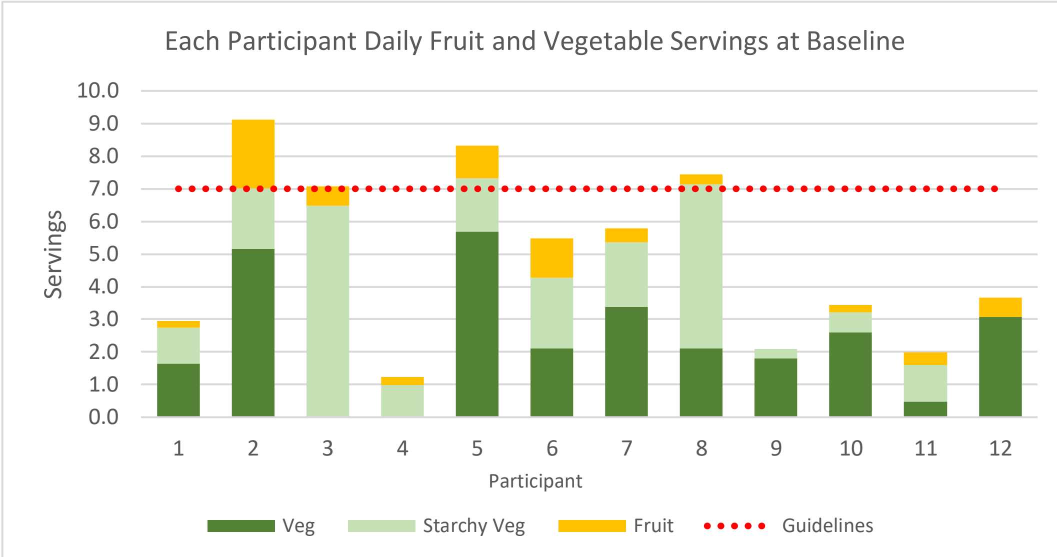
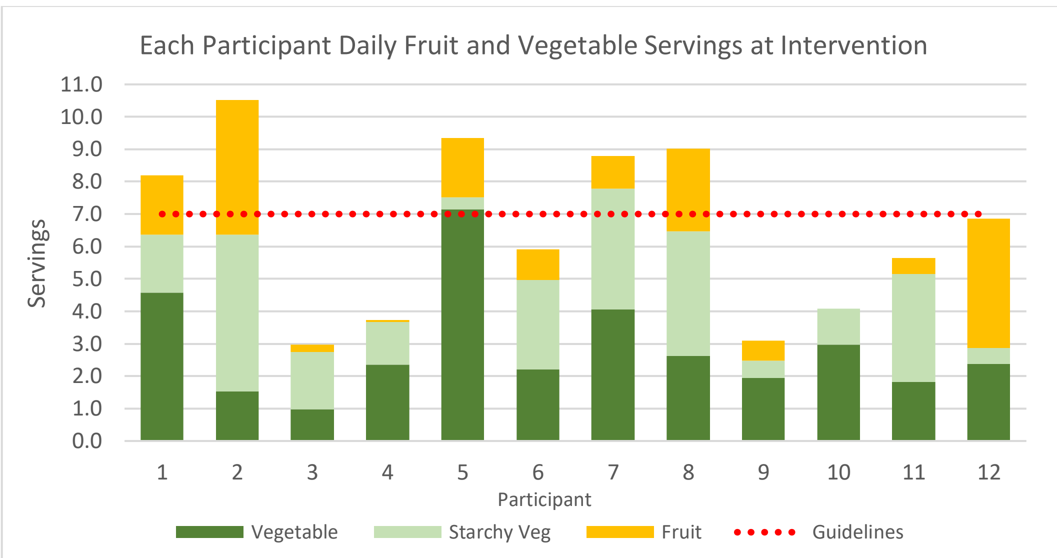


Figure 3.2 *Daily mean intake of fruit and vegetable at baseline & endpoint.*





The 2020 Ministry of Health Eating and Activity Guidelines recommends 5+ servings of vegetables (includes starchy vegetable that is fried/boiled/roasted) and 2+ servings of fruits per day. The starchy vegetable is separated in this chart to show how much it contributes to overall vegetable servings.

Figure 3.3 *Participant fruit and vegetable serving sizes at baseline vs intervention, and its comparison with the Ministry of Health Guidelines*

3.4.3 Vegetable intake

The mean intake of vegetables increased by 40 ± 154g/d and 0.5 ± 2.1 servings/day, whilst starchy vegetable intake remained the same across the study period (Table 3.4 & Figure 3.3).

Around 50% of the vegetable intake came from starchy vegetables at both timepoints. Three (25%) participants increased their vegetable servings by ≥ 1.0 serving/day during intervention. Overall, only five (43%) participants met the MoH recommendations of five servings of vegetable per day, which increased to seven (58%) participants at endpoint (Figure 3.3). Figure 3.4 shows the daily average allocated amount of F/V in the box during the intervention, and half of the given vegetables were eaten: potatoes (50%), kumara (47%), carrots (46%), onions (39%), broccoli (33%) and cabbage (17%).

In comparison to other vegetable groups, the intake of allium vegetable group increased significantly during the study (p = 0.05) (Table 3.4). Tomatoes and vegetables contributing to starch were less frequently at endpoint by 28% and 21%, respectively. On the contrary, the most frequently consumed vegetable groups were starchy vegetables (72%), followed by allium (62%), yellow-vitamin-A vegetables (54%), tomatoes (54%) and green-vitamin-A vegetables (49%) and cruciferous vegetables (46%) (Figure 3.5). Amongst all the vegetables participants have eaten, the top five most consumed (summed intake) were potatoes (1940g), carrots (974g), tomato (791g), potato chips (732g), kumara (578g) (Appendix B, Figure 1).

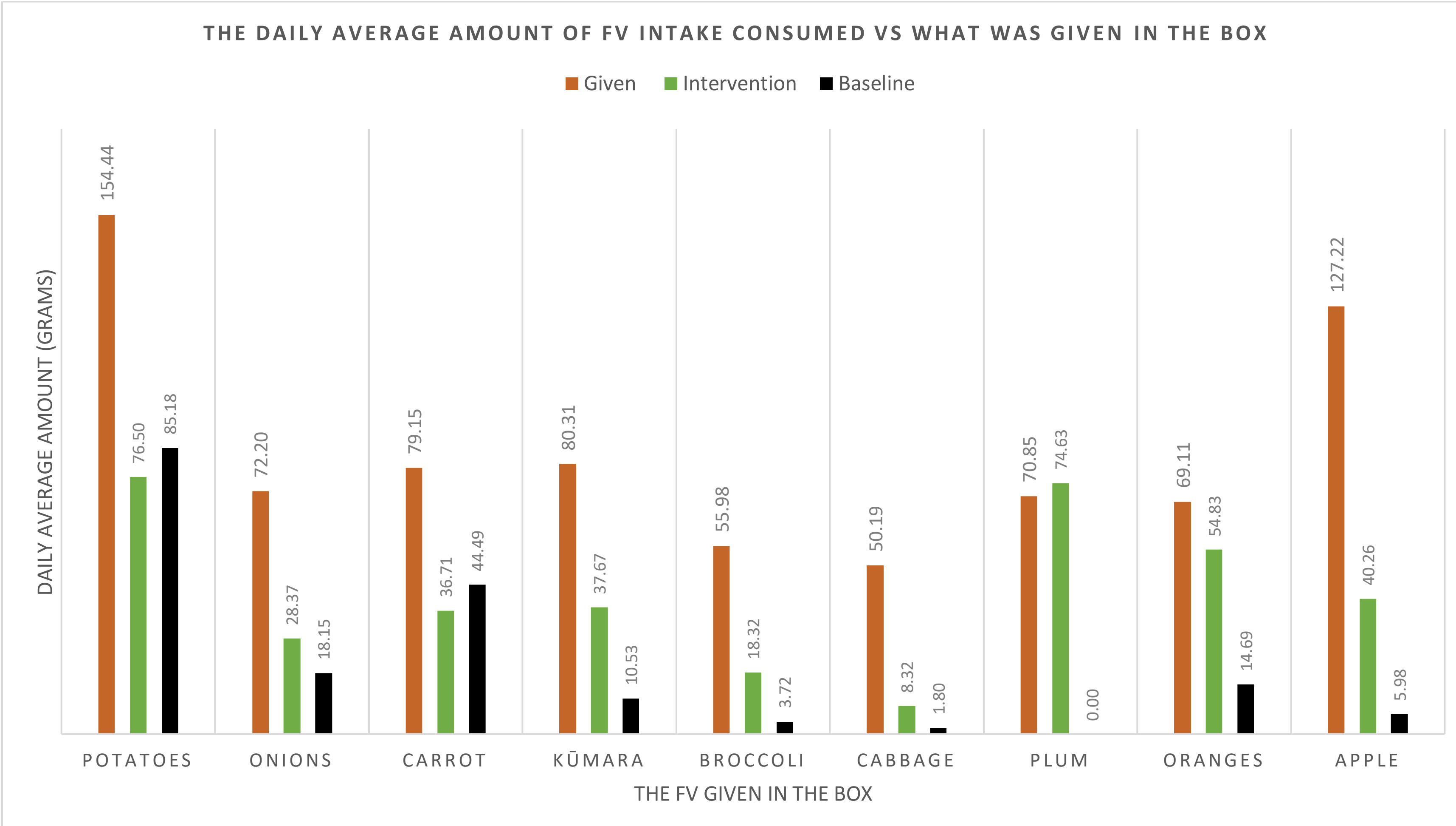
Overall, participants ate about 50% of their vegetables consumed in homemade meals (part of a recipe e.g., boil-up, stew, pasta, curry), and 22% of their vegetables as wholefoods (raw, roasted, boiled, in salads or in sandwiches) at baseline and 42% at end point (Appendix B, Figure 2).

Among demographic characteristics, those with three or more children in the household or living in state housing had an increase of ≥ 1.0 serving/day of vegetable. Smokers increased their intake by 2.0 servings/day of vegetables and non-smokers by 1.0 serving/day (Data are not shown).

Table 3.4 *Daily vegetable and vegetable groups intake (g) and servings during baseline and intervention*

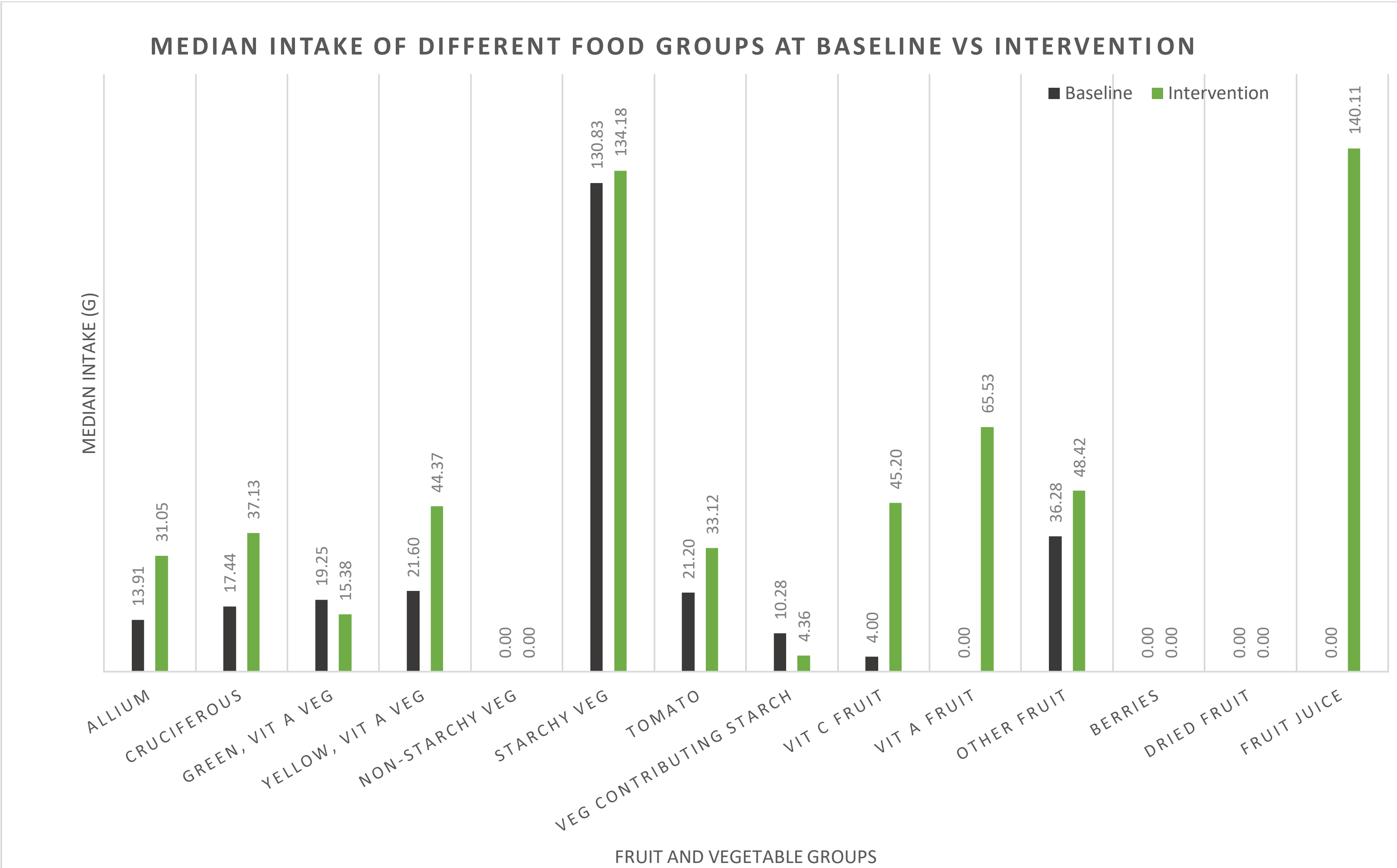
Vegetable Intake	**Baseline (n = 12)** Mean ±SD	**Baseline (n = 12)** Median (25-75th centile)	**Intervention (n = 12)** Mean ±SD	**Intervention (n = 12)** Median (25-75th centile)	Paired Difference	% Difference	*p* value*
Total Vegetable (servings)	4.5 ± 2.1		5.0 ± 1.9		0.5 ± 2.1	+32%	0.381
Starchy Vegetable (servings)	2.1 ± 1.9	-	2.2 ± 1.5	-	0.04 ± 2.0	+40%	0.951
Total Vegetable Intake (g)	338 ± 156	-	378 ± 140	-	39.8 ± 154	+32%	0.381
Starchy Vegetable Intake (g)	159 ± 145	-	161 ± 122	-	2.78 ± 154	+40%	0.509
Vegetable categories							
Starchy vegetables (g)	-	131 (72.6-182)	-	134 (72.8-256)	37.9g (-93.2- 110)	+46%	0.695
Vegetable contributing to starch (g)	-	10.3 (0.00-46.5)	-	4.36 (0.00-9.35)	0.00 (-55.5-0.01)	0%	0.123
Non-starchy vegetables (g)		0.00 (0.00-0.00)		0.00 (0.00-1.10)	0.00 (0.00-3.30)	0%	0.345
Allium Vegetables (g)	-	13.9 (3.43-25.5)	-	31.1 (8.64-47.1)	11.2 (1.16-28.1)	+21%	0.050
Cruciferous Vegetables (g)	-	17.4 (5.86-26.5)	-	37.1 (3.78-45.9)	16.3 (-16.2-43.4)	0%	0.239
Green-vitamin-A Vegetables (g)	-	19.3 (0.00-36.7)	-	15.4 (0.00-43.6)	3.83 (-15.5-27.9)	0%	0.646
Yellow-vitamin-A Vegetables (g)	-	21.6 (0.00-56.2)	-	44.4 (9.09-70.9)	8.51 (-4.69-39.5)	0%	0.534
Tomatoes (g)	-	21.2 (1.82-46.5)	-	33.1 (0.00-55.4)	-1.05 (-30.6-26.5)	-8%	0.790

1.0 serving of vegetable = 75g
* Significance tested either with dependent paired t-test with normally distributed data or Wilcoxon-signed rank test with non-normally distributed data, and using alpha level of
$p < 0.05$ to denote statistical significance. Only a few vegetable groups were normally distributed data, hence all vegetables groups were treated as non-normally distributed so the data can be compared. Paired difference calculation: the mean or median of each participant's difference. % difference calculation: participant's intake at intervention minus baseline, divided by baseline and multiple by 100%, then get the mean or median value of every participant's % difference.
Total vegetable includes starchy vegetable. Starchy vegetables = potato, kumara, corn, taro, cassava; Vegetables contributing to starch = beetroot, peas, pumpkin, squash, vegetable mix; Non starchy vegetables = mushrooms, celery, asparagus, eggplant, green beans, mung beans); Allium = onion, leek, spring-onion, garlic



Sweet potato was the tenth vegetable given in the box however taken out for analysis as no participant reported sweet potato in their 24-hour recall as kumara is sweet potato. "Daily average given amount" calculation = the total fruit/vegetable given (kg) divided by # of members in household, divided by seven days. E.g. (8.6kg potatoes ÷8 members) ÷ 7 days = 1.075kg ÷ 7days = 154g. The amount eaten by participant is their mean daily intake.

Figure 3.4 *The daily average amount of the fruit and vegetable given in the box per participant versus how much fruit and vegetables were consumed by participants during baseline and intervention*



The data collected at baseline were 3-weeks and intervention were 4-weeks.

Figure 3.5 *The comparison of daily median intake of fruit and vegetable categories at baseline vs intervention*

3.4.4 Fruit Intake

There was a significant difference in the daily median intake and servings of fruit (*p* = 0.05). Other fruit results are shown in Table 3.5. More than half of the participants (67%) increased their fruit consumption by 1.4 servings/day, and one-third (33%, n = 4) increased by 1.0 serving/day during intervention. Most (92%, n = 11) participants ate below the MoH recommendations of 2 servings/day of fruits at baseline vs 75% (n = 9) at endpoint. Out of the three fruits that were given to households for free, participants ate more than their allocated daily average of plums (105%), followed by oranges (79%) and apples (32%) (Figure 3.4).

In comparison to other fruit groups, intake of **v**itamin A fruits (*p* = 0.01) and fruit juice (*p* = 0.03) increased significantly during the study period (Table 3.5). Fruit juice and **v**itamin A fruits such as plums, mangoes and watermelon were consumed more frequently than any other fruit groups by 21% and 16%, respectively. Amongst all the fruit participants have eaten, the largest consumption (summed intake) were plums (895g), oranges (834g), apples (555g), kiwifruit (263g) and watermelon (221g) (Appendix B, Figure 1).

Among demographic characteristics, those who rented increased their fruit intake by 2.0 servings/day and those in state housing decreased by 0.2 servings/day. Most (92%, n = 11) households with children increased their fruit intake by at least 0.5 servings/day at endpoint. Daily fruit intake increased by 2.0 servings/day in non-smokers and 1.0 serving/day in smokers. (Data not shown).

Table 3.5 *Daily median of fruit and fruit group intake (g) & servings during baseline and intervention*

	Baseline (n=12)	**Intervention (n=12)**			
Fruit Intake	Median (25-75th centile)	Median (25-75th centile)	Paired Difference Median (25-75th centile)	% Difference	*p* value*
Fruit (servings)	0.4 (0.2-1.0)	1.0 (0.3-2.4)	0.6 serves (-0.2-1.9)	+52%	0.050
Fruit Intake (g)	62.3 (35.9-150)	146 (41.7-355)	90.0 (-33.9-292)	+52%	0.050
Fruit Categories					
Vitamin C Fruits (g)	4.00 (0.00-78.2)	45.2 (0.00-141)	22.3 (0.00-87.3)	14%	0.093
Vitamin A Fruits (g)	0.00 (0.00-0.00)	65.5(0.00-103)	65.5 (0.00-119)	0%	0.011
Other Fruits (g)	36.3 (22.1-70.0)	48.4 (26.9-71.8)	-19.3 (-48.1-44.2)	-34%	0.754
Berries (g)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0%	0.593
Dried-fruit (g)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0%	0.180
Fruit Juice Intake (g)	0.00 (0.00-101)	140 (0.00-346)	56.4 (0.00-346)	0%	0.025

1.0 serving of fruit = 150g

* Values were tested using the non-parametric Wilcoxon-Signed-rank test at significance $p > 0.05$

Paired difference calculations: the mean or median of every participant's difference; % difference calculation: participant's intake at intervention minus baseline, divided by baseline and multiple by 100%, then get the mean or median value of every participant's % difference.

Fruit intake and servings excludes fruit juice.

Vitamin C fruit = mandarins, oranges, kiwifruit, grapefruit, lemon, lime; Vitamin A Fruits = apricot, plum, watermelon, mango, persimmon, melon; Other fruits = apple, banana, grape, feijoa, pear, peaches, pineapple, guava, papaya, lychee, passionfruit, cherry.

3.4.5 Fruit and Vegetable Diversity

In table 3.6, the overall number of fruit and vegetable diversity consumed remained the same throughout study period. Those who ate 7 or more varieties of F/V increased by two participants (17%) at endpoint. The additional F/V eaten between the two groups at endpoint are shown in table 3.4. The F/V diversity questionnaire results also showed the most frequently eaten vegetables were potatoes (67%), tomatoes (60%), onions (60%), carrots (40%) and lettuce (36%) (Appendix B, Figure 1). And the most frequently eaten fruits were apples (25%), oranges (25%), banana (15%), fruit juice (14%) (Appendix B, Figure 1).

Table 3.6 *Participants who ate an average of 7+ varieties of fruit and vegetable per day, and a list of different and commonly eaten fruit and vegetable between the two groups*

	Number of participants	Baseline	Number of participants	Intervention
Common food eaten by all participants	n = 12	Potato, onion, tomato, corn, beans, peas, broccoli, cauliflower, cabbage, apple, banana, pear, pineapple, apricot, peach, avocado (n = 16 varieties)	n = 12	**Potato**, **onion**, tomato, corn, **lettuce**, **carrot, broccoli**, beetroot, peas, capsicum, mushrooms, spinach, avocado, **kumara**, **apple, orange**, banana, pineapple, apricot, pear, **plum**, kiwifruit (n = 22 varieties)
Those who ate > 7 varieties	n = 4	Beetroot, casava, cucumber, capsicum, mushrooms, spinach, taro, taro leaves, mandarins, kiwifruit, papaya, coconut, cranberry, blueberry, mango, passionfruit (n = 16 varieties)	n = 6	Cucumber, courgette, watercress, puha, pumpkin, **cabbage**, strawberries, peach, grapes, nectarine, calamsi, watermelon (n = 12 varieties)
Those who ate < 7 varieties	n = 8	Celery, bok choy, olives, grapes (n = 4 varieties)	n = 6	Ginger, parsley, blueberries (n = 3 varieties)

Bolded fonts = The nine fruit and vegetables given for free to participants
MOH Eating and Activity Guidelines recommends 5+ servings of vegetables and 2 servings of fruit per day, hence the number of fruit and vegetable diversity is also set at 7 varieties per day.

3.4.6 Skin Carotenoid Status

Wilcoxon signed-rank test showed no significant difference in VM scores from baseline to endpoint (*r* = -0.340, *p* = 0.239). Spearman's rho correlation coefficient was used to assess the relationship between VM scores and F/V intake, and there were no significant correlations observed as shown in Table 3.7.

Table 3.7 *The association of skin carotenoid status with F/V intake at baseline and endpoint*

	Baseline n = 11 Median (25-75th centile)	Intervention n = 11 Median (25-75th centile)	Paired Difference
Veggie Meter® scores	235 (170-285)	246 (170-273)	11 (-14 – 36)
Vegetable intake	*r* = -0.112	*r* = 0.126	*r* = 0.168
	p = 0.703	*p* = 0.697	*p* = 0.602
Fruit intake	*r* = -0.176	*r* = 0.315	*r* = 0.035
	p = 0.547	*p* = 0.319	*p* = 0.914
Vitamin A rich F/V intake	r = -0.135	*r* = 0.105	*r* = 0.028
	p = 0.646	*p* = 0.746	*p* = 0.931
Total F/V servings	*r* = -0.134	*r* = 0.217	*r* = 0.091
	p = 0.648	*p* = 0.499	*p* = 0.779

Correlations tested with Spearman's correlation, significance at $p < 0.05$; F/V: fruit and vegetable.
There was one missing Veggie Meter score at baseline. Veggie Meter took 3 readings and was averaged for the final score. Paired difference calculation: The difference of every participant's Veggie Meter scores at baseline and intervention, then took a median value.

VM scores were split into two groups, those below and above the cut-off score of 250. A significant correlation was observed with vitamin A rich F/V intake in the two groups at both timepoints (Table 3.7). Participants who scored ≥250 on the VM ® had a significant correlation with overall F/V servings across the entire study period (baseline *p* = 0.04, intervention *p* = 0.03), and fruit intake (*p* = <0.05) but at end point only (Table 3.8). Smoking is a potential determinant of skin carotenoid status and no associations were observed as shown in Appendix B, Table 1.

Table 3.8 *The association between the two VM cut-off scores and F/V intake baseline and intervention*

	Baseline		Intervention	
VM cut-off score	<250 (n = 6)	≥250 (n = 5)	<250 (n = 6)	≥250 (n = 5)
Vegetable Intake	p = 0.612	***p* = 0.043**	p = 0.753	p = 0.116
Fruit Intake	p = 0.398	p = 0.080	p = 0.753	***p* = 0.046**
Yellow-Vit A F/V intake	***p* = 0.018**	***p* = 0.043**	***p* = 0.028**	***p* = 0.028**
F/V servings	p = 0.310	***p* = 0.043**	p = 0.463	***p* = 0.028**

Correlations were tested with Wilcoxon Signed-ranked test. For example, the correlation between VM score < 250 vs vegetable intake at baseline is p = 0.612, ***p* <0.05 denotes significance**. F/V: fruit and vegetable
Only 11 participants VM scores were analysed because there was one missing data at baseline.

3.4 Discussion

3.4.1 Total Fruit and Vegetable Intake

There were three main findings relating to the total F/V intake. First, there was no significant difference in combined F/V servings pre-and post-intervention (p = 0.065), despite participants increased F/V intake by 1.4 ± 2.4 servings per day. In the 2020-21 NZ Health Survey only 32% of Māori women met the current MoH guidelines (Ministry of Health 2020), similarly, 33% (n = 4) of the participants in this study met the guidelines post-intervention. This means more than half of the participants have failed to meet the recommended servings of F/V, which is similar to findings from Pezdirc et al. (2015), where 83.5% of Australian women did not meet the Australian guidelines (same as NZ guidelines). And Similarly 61.5% of European/other women living in NZ did not meet the guidelines (Ministry of Health, 2021). In this study, barriers were not explored but a small sample size due to the feasibility design and participants' large diet variations may explain why no significant differences were observed.

Secondly, half of the given vegetables were not consumed by the participants; however, other members in the household may have benefitted from the remaining F/V. Thirdly, five participants reported to the RA's that they gave away free F/V to whānau, which is in line with other studies that reported gifting to be a common practice in Māori culture, as an expression of manākitanga (respect and hospitality) (Beavis et al., 2019; Mackay et al., 2018). Out of the nine F/V given in the box, six were already commonly consumed at baseline, such as potatoes, onions, carrots, kumara, apples and oranges. This may be another reason why the participants gifted to their whānau and did not eat all the free F/V. However, it is important to consider that the 24-h recall was conducted on randomised days per week and thus did not necessarily capture all the days the free F/V may have been eaten.

3.4.1.1 Fruit and Vegetable Diversity

The main finding from using the F/V diversity questionnaire was the participants' lack of food knowledge in terms of what constitutes a F/V item. On 29 occasions the questionnaire did not match the 24-h recall answers. For example, 27% of tomato intake was based on consuming ketchup (tomato sauce), 20% of orange juice intake was mistaken for orange flavoured soda, or 100% reconstituted juice and cordials, and 12% of self-reported potato intake was potato crisps (snacks, e.g., Bluebird chips). Furthermore, some participants coded "beans" either as baked-beans or green beans; "bok choy" was ticked as broccoli, and "cassava" ticked as potato because the list did not cover all F/V examples. Such mistakes were not corrected during analysis to prevent fabrication; therefore, the true F/V diversity intake may not be as diverse or frequently consumed.

As a result, the F/V diversity questionnaire was valuable to identify any misreporting. For example, 57% of identified food on the questionnaire was not recorded on the 24-h recall at baseline, and 27% at intervention. Fewer misreporting was observed at intervention because a RA training session was conducted immediately after reviewing the baseline data to optimise data collection.

Whilst the F/V diversity questionnaire lacked specificity (food definition), which hampered data validity, this novel tool provided two positive insights, confirming its value as part of the 24-h recall. The results showed the most frequently consumed F/V were potatoes, tomatoes, onions, carrots and lettuce, which were also the five most eaten vegetables amongst NZ European and Pasifika women in a NZ study by Richter (2021). While reasons for the variety consumed is not explored in this study, this was still important in providing some context for the eating behaviours around vegetable intake.

The second insight was two participants at each timepoint were able to recall their food intake when going through the questionnaire. This suggests the questionnaire did help the participant to cross-reference their information in the 24-h recall.

3.4.2 Vegetable intake

Starchy Vegetables

Participants met the recommended five servings of vegetables per day post-intervention, but nearly half were starchy vegetables (including fries), which do not provide as wide a range of micronutrients as non-starchy vegetables. These participants' vegetable intakes would have fallen short of the WHO standard of 400g of F/V per day, which excluded starchy vegetables. This means participants' combined F/V intakes including and excluding starchy vegetables respectively, were 401g vs 242g at baseline and 524g vs 363g at endpoint. This suggests participants' vegetable intakes were suboptimal, and promoting a range of non-starchy rainbow-coloured F/V consumption remains important. The MoH guidelines recommend having more non-starchy vegetables on the plate as starchy vegetables tend to be higher in energy. It is recognised that many traditional Māori kai and Pasifika dishes incorporate starchy vegetables, hence traditional kai is not discouraged (Ministry of Health 2020). While NZ recommends limiting deep-fried foods and crisps, other countries are more specific with their starchy vegetable recommendations. For example, the Australian Eating Guidelines - "increase consumption of vegetables, except those that are fried" (National Health and Medical Council, 2013); and in the United Kingdom Eatwell Guidelines – starchy vegetables are excluded from "five a day" F/V servings (Public Health England 2018). That is because they are often prepared in oil and/or fat (Public Health England 2018). A recent systematic review found the intake of potatoes (boiled, baked or mashed) had no association with the risk of cardiovascular disease and hypertension (HT), but 150g/d of French fries showed a positive association with increased risk of type 2 diabetes (RR: 1.66, 95% CI 1.43, 1.94), and HT (RR: 1.37, 95% CI 1.15–1.63) (Lukas Schwingshackl et al., 2019). This evidence is not only helpful for future studies to consider isolating fried potatoes as their own category, but also evidence for NZ policy makers to provide more parameters for potato consumption based on cooking methods.

In addition to issues with starchy vegetable intake, there was misreporting related to potatoes. Many participants in this study reported a "handful" (10 x French fries = 80g) of chips compared to the regular fries (punnet size of 150g) at fast food chains. Underreporting chips could have been due to using the most relatable or comfortable portion in the booklet. Nevertheless, underreporting energy intake in a 24-h recall has been found in other studies where respondent bias was a likely explanation because a nutritionist or dietitian was conducting the interview (Lins et al., 2016; Poslusna et al., 2009; Smith-Warner et al., 1997). In this study, respondent bias was unlikely to be a contributing factor because interviewers were Māori and worked with the community.

Non-starchy vegetables

There were three main findings among the vegetable categories. Intake of allium vegetables was significantly higher post-intervention, most likely because onions were given in the box and were often used in stews, sauces, soups etc. Although intake of cruciferous and yellow-vitamin-A rich vegetables increased at endpoint, participants did not eat these consistently, hence why there was no statistical significance. Lettuce and tomato were among the topmost consumed non-starchy vegetables and were found eaten mostly as a topping in sandwiches or burgers. These results further revealed that non-starchy vegetables were the least consumed food group for three plausible reasons. First, they are more expensive than starchy and allium vegetables. Secondly, they are not as commonly eaten; and third, participants may not have been exposed to these vegetables during early childhood (Carty et al., 2017). Furthermore, non-starchy vegetables were also not listed as the most widely consumed vegetables in the NZ population (Mainvil et al., 2011). Exploring barriers to eating a variety of vegetables in NZ is encouraged. Whilst there is an abundance of locally grown F/V in NZ, barriers to eating a variety of vegetables is prevalent. Perhaps more effort is needed to improve the food system to make locally grown F/V accessible and affordable.

3.4.3 Fruit intake

Past MoH reports indicated that Māori adults living in socioeconomically deprived areas were less likely to eat the recommended servings of fruits (Ministry of Health, 2019a), and that only

49.7% of Māori women consumed 2+ servings of fruit per day (Ministry of Health 2021a). The present analysis also found fewer than half of the participants (42%, n = 5) consumed 2+ servings fruit per day, despite a significant increase in fruit intake post-intervention. Overall, participants ate a median of 0.4 servings of fruit per day at baseline, which is less than the study by Jaeger et al. (2009), where participants living in high deprivation areas ate 5-6 servings per week (an average of 0.8 servings of fruit per day). From these results we may speculate that participants in this study may not routinely buy or eat fruit as often as vegetables.

In terms of fruit categories, both fruit juice and vitamin A fruit intakes were significantly increased across the study period. Fruit juice increased by 56g during intervention, signifying that low-income groups regularly drink commercial fruit juice. This behaviour mirrors the studies in Australia and the USA where juice consumption was highest among those in lower SES (Drewnowski et al., 2015; Nour et al., 2017). Although many dietary guidelines do not include fruit juice as a serving of fruit due its high sugar and low fibre content, juice intake should continue to be monitored. The high intake of vitamin A fruit was due to the free plums in the box as they were in season (February), and this may explain why participants were not buying nor eating plums at baseline (December). In this study, seasonality, gatherings and buying freshly made fruit smoothies were found to contribute to fruit diversity in their diets, such as watermelon, pineapple and berries.

3.4.4 Dietary Assessment Tool - 24-hour Recall

Strengths of the adapted 24-h recall

The literature suggested that having the interviewer from the same ethnic background as the participants may provide more reliable data because they have the existing knowledge of the cultural foods and norms and can able be less judgmental (DeBiasse et al., 2018; St George et al., 2016). This study engaged two Māori RAs and they performed well in building rapport with the participants, and their cultural background was critical when probing for specific cultural foods such as boil-ups and kahawai (raw fish). Their use of Te Reo Māori further helped the participants to open-up and feel comfortable discussing their food intake.

The ability to capture wider context around food consumption and F/V behaviours using the 24-h recall was a strength. For example, the collected data helped gain information on F/V groups, individual intake of F/V and types of meals. It further allowed comparison with serving sizes from the NZ dietary guidelines. The results also showed there were significant increases in fruit intake and various food groups, indicating that a 24-h recall can be a great instrument to measure and explore F/V intake. Other similar studies also used a 24-h recall to assess energy intake (Tooze et al., 2007); F/V intake (Jahns et al., 2019; Seguin-Fowler et al., 2021), and iron and zinc intakes (Gibson et al., 2008). Future studies can expand on the timing of food consumed, the location of preparation and eating of the food, cooking methods and nutrient analysis.

Limitations of the adapted 24-h recall

The key to conducting a successful 24-h recall is to collect accurate data. Measurement error is often reported as the main reason for data inaccuracy which was also evident in this study. For example, the RAs not using the portion size booklet during the interview; the RA's may have felt pressured to only use the portion codes or pictures provided in the booklet when participants provided other options; and a lack of probing when necessary. During 24-h recalls, reporting "palm-size" vs "handful" were often used inappropriately because the volume is not considered. In summary, the toolkit and booklet were tactile and visual to aid memory recall (Gregorič et al., 2019; St George et al., 2016), but the high occurrences of measurement errors indicated that RA training of using the resource was needed to improve the conceptualisation of portion sizes. As a result, this may reduce the number of assumptions during data analysis. Missing scanned 24-h recalls, audio recordings and demographic information further compounded the data analysis process. Some of the occurrences mentioned above may also have stemmed from the study logistics such as a lack of supervision and support for the RA's during data collection, alongside the Covid-related restrictions. These types of errors are not always reported in the literature and should be considered to be included for future studies.

For future studies, it is recommended that more intense training and practice is required for non-specialist RAs prior to data collection commencing, and that for the first few interviews, the dietitian/nutritionist is present as a silent observer to provide support and review as required to fill in the gaps during an interview. This should be followed by feedback and discussion after the interview to further optimise the data collection method. The FAO recommends "obtaining detailed data on individual dietary intake… requires a high level of technical skill both in data collection and analysis" (Food and Agriculture Organization, 2013), emphasising the importance of involving a dietitian/nutritionist to oversee and liaise the data collection procedures to ensure all data is captured accurately.

3.4.5 Skin Carotenoid Status

Servings of F/V and VM scores both showed no statistical significance between pre- and post-intervention measures; hence it was not surprising that there was no association between them. However, when we examined the relationship between those below and above the VM cut-off scores with F/V intake, some significant results were detected, despite the small sample size. A weak association was found between high VM scores (≥ 250) with yellow-vitamin-A F/V intake and F/V servings at both baseline ($p = 0.04$) and endpoint ($p = 0.03$). Another American study by Fultz et al. (2021) also found a similar correlation ($p = 0.02$) in low-income adults ≥60 years who had a mean VM score of 172, and in addition, their F/V intake did not meet the American Eating Guidelines. However, their study population was older people and skin pigmentation could be different due to the ageing skin (Fultz et al., 2021). Another F/V study suggested that the VM cannot detect all F/V intake because not all F/V contains carotenoids (May et al., 2020). This suggest participants' SCS are not a direct measure of their F/V intake.

The primary source of carotenoids in this study was likely from intake of carrots, tomatoes, kumara, capsicum, broccoli, plums, oranges and mandarins as they were frequently consumed. Pezdirc et al. (2015) found that Australian women's dietary intake of beta-carotenoids ($p < 0.01$), lutein and zeaxanthin ($p < 0.01$) was significantly associated with respective absorption spectra. An European study found that canned tomato and ketchup are very high in carotenoids, which were commonly consumed in this study (Dias et al., 2021). However, animal sources such as yolks of eggs, cheddar cheese and milk also contain vitamin A, therefore it is important to consider that the participants VM scores may not be entirely comprised of F/V, and thus not a true reflection of their F/V intake.

In summary, the correlation between SCS and self-reported F/V intake remains unresolved, similar to the current literature where studies found mixed results. Those studies which did not find a positive correlation suggested misreporting inconsistency being one of the main reasons (Beccarelli et al., 2017; Hill et al., 2021; Jahns et al., 2019; Martinelli et al., 2021). In an Alaskan community, the average of 2.5 F/V servings calculated from two 24-h recalls was not significantly correlated with VM scores (r = 0.15; p = 0.19). Furthermore, the same study suggests the inverse relationship with BMI and misreporting of participants are likely explanations for its insigificance (Hill et al., 2021). However, BMI was not examined in this study.

Smokers had a VM score of 208 ± 52 at baseline which was identical to the smokers in low-income Hispanic adults living in New Jersey (208 ± 67) (Di Noia et al., 2021). Although smokers have been shown to have a lower level of skin carotenoids, this study did not find any correlations, which is likely from having a small sample size and intake of other foods containing carotenoids.

Strength and Limitations of the Study

This study identified three additional strengths as follows. The developed 24-h recall, including the training manual and resources was a strength and served as a good foundation to train the RA with no prior nutrition or dietary assessment knowledge. The two Māori RA's have brought many assets to the study, such as the recruitment process and the ability to reduce respondent bias which was a big limitation in other studies. Furthermore, the audio recordings were valuable to review the 24-h recall data to improve overall data accuracy; it helped pinpoint unclear descriptions of foods or portions that may not have been included in the written 24-h recall record.

There were several limitations in this study. The main limitation was the feasibility study design with a small sample size. Consequently, it was difficult to draw conclusions on the associations between F/V intake and skin carotenoid status, and the data cannot truly represent the low-income Māori population. Another limitation of the study was the timeframe; it was conducted before and after Christmas holidays, which explained why many participants were away and reported “unusual intake” and “feast days” on their 24-h recalls. Furthermore, not every participant completed eight 24-h recalls due to their unavailability. The 24-h recall is subject to the day-to-day variability in the diet. Whereas the spectroscopy operated VM is subject to habitual diet intake, roughly up to eight weeks, therefore may not be an accurate measure for the short term F/V intakes in this study. The VM readings were not taken immediately after or before the 24-h recall, but randomised on separate days, which may also compromise comparisons. Above all, Covid-19 restrictions made it challenging for the student dietitian researcher to travel to Palmerston North and to observe the RA during measurement days.

3.6 Conclusion

This study demonstrated that using a 24-h recall is feasible and culturally safe to measure F/V intake in low-income Māori households. However, collecting accurate data is dependent on interviewer skills. Intake of fruit, vitamin A F/V and allium vegetables significantly increased across the study period, revealing that the participants benefitted from the fruit more than the vegetables in the free box. Despite half of participants meeting the daily recommended intake of vegetables, almost half of them were starchy vegetables. Only four of the twelve participants met the Ministry of Health (MoH) recommendations of both five servings of vegetables and two servings of fruit per day. Overall, there were no associations between SCS and F/V intake, but there was a weak association between VM scores ≥ 250 with intakes of fruit, Vitamin A F/V and F/V. This shows that quantifying SCS is sensitive to carotenoid consumption, thus can be a better tool to measure vitamin A F/V intake and as a proxy measurement of F/V intake.

Future studies should consider a longer training course for the RA and closer involvement of a dietitian or nutritionist during data collection to improve data accuracy. More specific examples and definitions on the F/V diversity questionnaire may prevent food literacy mistakes made by the participants. Although both the 24-h recall and Veggie Meter are feasible dietary assessment instruments, the 24-h recall can provide more context and information about food intake, making it suitable to measure F/V in Māori households living in deprived areas.

Chapter 4: Conclusion and Recommendations

4.1 Overview

Inadequate F/V intake increases the risk of coronary heart disease and obesity, and obesity rates among Māori are 1.7 times higher than NZ European adults (Ministry of Health, 2019b). Māori living in low socioeconomically deprived areas are at nutritional risk due to the systemic inequalities that can leave them food insecure (Moeke-Pickering et al., 2015). In order to promote F/V intake and improve health outcomes in this population, we need to know their current F/V intake by using a validated dietary assessment tool. To date, little is known regarding which instrument is the most feasible and culturally suitable for the assessment of F/V consumption in a low-income Māori population. These tools can contribute collecting more reliable data for epidemiological studies, and direct dietitians and other key stakeholders to evaluate and implement action on building a more sustainable food network for whānau, and most importantly, improving long-term health outcomes in Māori communities.

4.2 Main findings

Objective 1: To develop a 24-h recall method to be used by Māori RAs' to collect fruit and vegetable intake data from Māori households.

Findings: The developed multiple-pass 24-h recall method had three steps to make training easier for the RA's. Step one: allowed the participant to briefly list all the food and beverages consumed in the past 24 hours without any interruptions. Step two: used probing questions to guide participants to recall the details of each item consumed. The developed portion size booklet and dishware toolkit was utilised to assist with estimation. Step three: summarised all recorded items and went through the F/V diversity questionnaire. The main finding was that the developed method was successful in collecting F/V intake data from a Māori population living in a high deprivation area. A further finding using this method was that data accuracy is dependent on the interviewer's skills and knowledge, specifically their guidance regarding estimation of portion sizes by participants. This led to recommendations 1-7 listed below to further minimise measurement errors. The additional novel tool to the 24-h recall method – the F/V diversity questionnaire was able to help us identify misreported items, and helped participants to remember forgotten foods, in addition to measure diversity of F/V consumption.

Objective 2: To train the research assistants to conduct the 24-h recall.

Findings: The RAs received four training sessions regarding: 1) the protocol of the developed 24-h recall; 2) role-playing to demonstrate a 24-h food recall being conducted; 3) group discussions on troubleshooting hypothetical obstacles; 4) how to estimate and record portion sizes using the portion size-booklet, toolkit and utilise other available resources such as their mobile phone; 5) learn the difference between "fist size" vs "handful" vs "palmful". Additionally, feedback was given during training and during data collection via email and Zoom calls. All sessions were recorded on computer to provide evidence for evaluation, and perhaps a training video for future use. Despite all the training, measurement errors still occurred, which maps to recommendations 2-7 listed below. Overall, the RAs were able to learn quickly but more quality control procedures should be implemented during each stage of measurement to minimise errors.

Objective 3: Evaluate and compare the F/V intake at baseline and end of intervention with the NZ Eating and Activity guidelines.

Findings: Even though the total F/V intake increased from 5.1± 2.4 to 6.5± 2.7 servings/day from pre- to post-intervention, no significant difference was found ($p = 0.065$). The reason was likely because only one (8%) participant met both five servings of vegetables and two servings of fruits per day at baseline, and four participants (50%) at endpoint. Likewise, most (92%, n = 11) participants failed to achieve the MoH guidelines for fruit at baseline vs 75% (n = 9) at endpoint. Whilst five (43%) participants achieved the MoH guidelines for vegetables at baseline and seven (58%) at endpoint. This suggests F/V intake remains suboptimal in Māori women, and they were less likely to eat fruit than vegetables, hence benefitted from the free fruit more than the vegetables during the intervention. In summary, we can accept the first hypothesis: there was no difference in F/V consumption pre- and post-intervention due to the potential behavioural barriers such as time, taste, personal preference, fixated habits, attitudes and beliefs towards F/V, and food and nutrition knowledge deficit.

Objective 4: Describe the fruit and vegetable intake in a low-socioeconomic Māori population pre- and post-intervention using the 24h-recall method.

Findings: The total F/V intake pre-intervention increased from 401 ± 215g/d to 524 ± 288 g/d post-intervention. However, intake of yellow-coloured vitamin A F/V (p = 0.002) and fruit (p = 0.05) showed the most significant increase post-intervention. In terms of vegetables, the most frequently consumed across the study were potatoes, tomatoes, onions, carrots and lettuce. Out of the eight vegetable categories, allium (62%), yellow-vitamin-A vegetables (54%) and tomatoes (54%) were the most consumed. The majority of vegetables were eaten as part of a homemade meal. Plums, oranges and apples were the most consumed fruit at endpoint, due to being given in the free box. Among demographic characteristics, the one household with four children increased their daily F/V from 3.0 to 8.2 servings. Most (92%, n = 11) households with children increased their fruit intake by at least 0.5 servings/day at endpoint. Those who rented (n = 6) increased their fruit intake by 2.0 servings/day.

Objective 5: Assess the effectiveness of the 24-h recall method by comparing the change in the change in fruit and vegetable intake with the change in skin carotenoid status.

Findings: There were no significant differences in overall F/V intake (p = 0.065) and VM scores (p = 0.239) between baseline and endpoint. Hence, there was also no association detected between F/V intake and VM scores (p = 0.779). When VM scores are broken into those below and above cut-off score of 250, five participants with high VM (≥ 250) scores showed a weak correlation with yellow-vitamin-A F/V and F/V intake pre- (p = 0.04) and post-intervention (p = 0.03), additionally, fruit intake at intervention ($p < 0.05$). Despite the small sample size, the weak correlations detected within sub-groups revealed that the 24-h recall method is feasible in measuring F/V. However, SCS may not serve as the best objective tool to determine F/V intake because it is more sensitive to the changes in carotenoids consumption.

In summary, we can accept the second hypothesis - the re-adapted 24-h recall method has been demonstrated as a feasible tool to capture dietary data based on the findings of objectives 3-5. Also, based on the findings of each objective, the use of both subjective and objective methods, the 24-hour food recall and Veggie Meter were reliable tools for assessing the accuracy of 24-h recall in a low-socioeconomic Māori population. In the same way, both instruments used in conjunction to measure F/V may be warranted and may serve as a better tool to measure vitamin A intake.

4.3 Strengths

This was one of the very few feasibility studies to shed light on validating dietary assessment tools in low-income Māori communities. The study involved staff from the Te Wakahuia Manawatū Trust as RAs. Their cultural background and extensive knowledge of the community were assets to work with the Māori population. As well as this, the 24-h recall, developed resources and training manual were specifically designed for this study. Furthermore, a significant strength of the secondary analysis was the inclusion of diversity of F/V and types of meals. This allowed for uncovering more F/V used in meals as well as a richer description of F/V consumption in this community.

4.4 Limitations

External limitations

This sub-study only examined two dietary assessment instruments out of four instruments used in the main study, therefore the RAs were already receiving a lot of training, which may have been a high burden for them. The data collection was rescheduled from August-September to December-February due to unforeseen delays; hence some participants were away for holidays, resulting in missing measurement days. Moreover, the F/V diversity questionnaire was designed to accommodate the seasonality of F/V in August, hence some items, such as capsicum and cucumber, were not included. The study design was re-adjusted during the washout period, to optimise the data collection for feasibility, for example the intervention timeframe was extended by another week. The logistics of data collection was difficult for the researcher to assist the RA in person due to study logistics, traveling distance and COVID-19 restrictions.

Internal limitations

This study had a very small sample size due to the nature of a feasibility study, as a result, participants' mean and median intakes were heavily affected by the large variations of dietary intake. For example, many ate 0g of carrots but one person ate 900g of carrots in one sitting, which may have resulted in skewed data. Hence, every recall was included regardless if eight were not completed, except for dropouts. Furthermore, the process of analysing the raw data required a lot of assumptions to best estimate the participants' realistic intake, which may have been either underestimated or overestimated. Lastly, this study did not ask for supplement intake which can highly influence SCS.

4.5 Recommendations

<u>Recommendations to the 24-h recall to improve quality and accuracy of data collection:</u>

1) Audio record the 24-h recall interviews to assist with clarification on the 24-h recall data analysis process, as well as, serve as back-up data.
2) Allow a dietitian/nutritionist monitor ± 5 percent of the RA's interviews to ensure consistency in the interview method between participants (Gibson & Ferguson, 1999). This process can also address other practical and ethical concerns.
3) Extend the RA training course to at least seven days to achieve proficiency (Gibson & Ferguson, 1999). Training should also include giving homework; practising/ role-playing on whānau; practising using the toolkits to estimate portion sizes, and to include more recipes to practice probing complex meals.
4) All 24-h recalls should be collected by the dietitian or main investigator at the end of day for immediate processing to ensure they are neat, legible, properly recorded and have no missing data to allow for follow-up if required.
5) Involve a dietitian/nutritionist throughout the entire data collection process to answer questions, resolve problems, assist RAs and give feedback on the progress of the 24-h recall.
6) Further calibrate all equipment in the dishware toolkit using real foods prior to data processing to minimise assumptions and estimations during data analysis.
7) Add more equipment to provide better visualisations for participants, for example:
    - Purchase seasonal F/V and weigh them prior.

- Prepare food models from play dough or foam rubber or papier-mâché, such as making the chips or toppings in sandwiches.
- Take your own photography of the most eaten meals and foods and weigh them, e.g., air-fried frozen chips, boil-up, sandwiches and burgers.

8) Update the F/V availability in the area closer to data collection start date to ensure all appropriate items are listed. For example, add mushrooms, capsicum, avocado and berries onto the F/V diversity questionnaire.
9) Provide more specific examples on the F/V diversity questionnaire, for example, "Beans (snap beans, snow-peas)", "Tomato (excludes ketchup)", "Potato (excludes chips and packet crisps)" to reduce food literacy related mistakes (see Appendix A, Table 3 for an improved Diet Diversity Questionnaire).

<u>For future feasibility and F/V studies, the following recommendations should be considered:</u>

1) Consider offering other seasonal water-rich vegetables in the free box, such as kale, capsicum, cauliflower, green beans, silver-beet, eggplant and cucumber that are widely grown in NZ or in the local region.
2) Explore barriers of F/V consumption, especially fruit intake and F/V diversity.
3) Separate "fried potatoes" as its own vegetable category to gain a better understanding of people's vegetable servings in NZ.
4) Have a large sample size to compensate the extreme variations between people's dietary intake and establish validity of these instruments.
5) Include body weight index (BMI) as a variable to examine the association with skin carotenoids status.
6) Assess the effectiveness of a 24-h recall with SCS to determine vitamin A rich food intake, rather than F/V intake.

Reference

Al-Sheraji, S. H., Ismail, A., Manap, M. Y., Mustafa, S., Yusof, R. M., & Hassan, F. A. (2013). Prebiotics as functional foods: A review. *Journal of Functional Foods, 5*(4), 1542-1553. doi:https://doi.org/10.1016/j.jff.2013.08.009

Alkazemi, D., & Salmean, Y. (2021). Fruit and Vegetable Intake and Barriers to Their Consumption among University Students in Kuwait: A Cross-Sectional Survey. *J Environ Public Health, 2021*, 9920270. doi:10.1155/2021/9920270

Andersen, L. F., Jacobs, D. R., Jr., Gross, M. D., Schreiner, P. J., Dale Williams, O., & Lee, D. H. (2006). Longitudinal associations between body mass index and serum carotenoids: the CARDIA study. *Br J Nutr, 95*(2), 358-365. doi:10.1079/bjn20051638

Atkinson et al. (2014). Neighbourhood deprivation

Aune, D., Giovannucci, E., Boffetta, P., Fadnes, L. T., Keum, N., Norat, T., . . . Tonstad, S. (2017). Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality-a systematic review and dose-response meta-analysis of prospective studies. *Int J Epidemiol, 46*(3), 1029-1056. doi:10.1093/ije/dyw319

Bazzano, L. A., He, J., Ogden, L. G., Loria, C. M., Vupputuri, S., Myers, L., & Whelton, P. K. (2002). Fruit and vegetable intake and risk of cardiovascular disease in US adults: the first National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. *The American Journal of Clinical Nutrition, 76*(1), 93-99. doi:10.1093/ajcn/76.1.93

Beavis, B. S., McKerchar, C., Maaka, J., & Mainvil, L. A. (2019). Exploration of Māori household experiences of food insecurity. *Nutr Diet, 76*(3), 344-352. doi:10.1111/1747-0080.12477

Beccarelli, L. M., Scherr, R. E., Dharmar, M., Ermakov, I. V., Gellermann, W., Jahns, L., . . . Zidenberg-Cherr, S. (2017). Using Skin Carotenoids to Assess Dietary Changes in Students After 1 Academic Year of Participating in the Shaping Healthy Choices Program. *J Nutr Educ Behav, 49*(1), 73-78.e71. doi:10.1016/j.jneb.2016.09.007

Bi, Y., Lv, M., Song, C., Xu, W., Guan, N., & Yi, W. (2016). AutoDietary: A Wearable Acoustic Sensor System for Food Intake Recognition in Daily Life. *IEEE Sensors Journal, 16*(3), 806-816. doi:10.1109/JSEN.2015.2469095

Buck-McFadyen, E. V. (2015). Rural food insecurity: When cooking skills, homegrown food, and perseverance aren't enough to feed a family. *Can J Public Health, 106*(3), e140-146. doi:10.17269/cjph.106.4837

Bulungu, A. L. S., Palla, L., Priebe, J., Forsythe, L., Katic, P., Varley, G., . . . Ferguson, E. L. (2021). Validation of a life-logging wearable camera method and the 24-h diet recall method for assessing maternal and child dietary diversity. *British Journal of Nutrition, 125*(11), 1299-1309. doi:10.1017/S0007114520003530

Burrows, T. L., Williams, R., Rollo, M., Wood, L., Garg, M. L., Jensen, M., & Collins, C. E. (2015). Plasma carotenoid levels as biomarkers of dietary carotenoid consumption: A systematic review of the validation studies. *Journal of Nutrition & Intermediary Metabolism, 2*(1), 15-64. doi:https://doi.org/10.1016/j.jnim.2015.05.001

Callender, C., Liu, Y., Moore, C. E., & Thompson, D. (2017). The baseline characteristics of parents and African American girls in an online obesity prevention program: A feasibility study. *Preventive Medicine Reports, 7*, 110-115. doi:https://doi.org/10.1016/j.pmedr.2017.05.011

Carty, S. A., Mainvil, L. A., & Coveney, J. D. (2017). Exploring family home food environments: Household resources needed to utilise weekly deliveries of free fruits and vegetables. *Nutr Diet, 74*(2), 138-146. doi:10.1111/1747-0080.12296

Darvin, M. E., Sterry, W., Lademann, J., & Vergou, T. (2011). The Role of Carotenoids in Human Skin. *Molecules, 16*(12), 10491-10506. Retrieved from https://www.mdpi.com/1420-3049/16/12/10491

Dauchet, L., Amouyel, P., Hercberg, S., & Dallongeville, J. (2006). Fruit and vegetable consumption and risk of coronary heart disease: a meta-analysis of cohort studies. *J Nutr, 136*(10), 2588-2593. doi:10.1093/jn/136.10.2588

DeBiasse, M. A., Bowen, D. J., Quatromoni, P. A., Quinn, E., & Quintiliani, L. M. (2018). Feasibility and Acceptability of Dietary Intake Assessment Via 24-Hour Recall and Food Frequency Questionnaire among Women with Low Socioeconomic Status. *J Acad Nutr Diet, 118*(2), 301-307. doi:10.1016/j.jand.2017.08.011

Di Noia, J., & Gellermann, W. (2021). Use of the Spectroscopy-Based Veggie Meter® to Objectively Assess Fruit and Vegetable Intake in Low-Income Adults. *Nutrients, 13*(7), 2270. Retrieved from https://www.mdpi.com/2072-6643/13/7/2270

Dias, M. G., Borge, G. I. A., Kljak, K., Mandić, A. I., Mapelli-Brahm, P., Olmedilla-Alonso, B., . . . Meléndez-Martínez, A. J. (2021). European Database of Carotenoid Levels in Foods. Factors Affecting Carotenoid Content. *Foods, 10*(5), 912. Retrieved from https://www.mdpi.com/2304-8158/10/5/912

Dibsdall, L. A., Lambert, N., Bobbin, R. F., & Frewer, L. J. (2003). Low-income consumers' attitudes and behaviour towards access, availability and motivation to eat fruit and vegetables. *Public Health Nutr, 6*(2), 159-168. doi:10.1079/phn2002412

Drewnowski, A., & Rehm, C. D. (2015). Socioeconomic gradient in consumption of whole fruit and 100% fruit juice among US children and adults. *Nutr J, 14*, 3. doi:10.1186/1475-2891-14-3

Drisdelle, C., Kestens, Y., Hamelin, A.-M., & Mercille, G. (2020). Disparities in Access to Healthy Diets: How Food Security and Food Shopping Behaviors Relate to Fruit and Vegetable Intake. *J Acad Nutr Diet, 120*(11), 1847-1858. doi:https://doi.org/10.1016/j.jand.2020.03.020

Eggersdorfer, M., & Wyss, A. (2018). Carotenoids in human nutrition and health. *Arch Biochem Biophys, 652*, 18-26. doi:10.1016/j.abb.2018.06.001

Ermakov, I. V., Ermakova, M., Sharifzadeh, M., Gorusupudi, A., Farnsworth, K., Bernstein, P. S., . . . Gellermann, W. (2018). Optical assessment of skin carotenoid status as a biomarker of vegetable and fruit intake. *Archives of biochemistry and biophysics, 646*, 46-54. doi:10.1016/j.abb.2018.03.033

Ermakov, I. V., & Gellermann, W. (2012). Dermal carotenoid measurements via pressure mediated reflection spectroscopy. *Journal of Biophotonics, 5*(7), 559-570. doi:10.1002/jbio.201100122

Ezzati, M., Lopez, A. D., Rodgers, A., Vander Hoorn, S., & Murray, C. J. L. (2002). Selected major risk factors and global and regional burden of disease. *The Lancet, 360*(9343), 1347-1360. doi:https://doi.org/10.1016/S0140-6736(02)11403-6

Food and Agriculture Organization. (2013). *Guidelines for measuring household and individual dietary diversity* Retrieved from https://www.fao.org/3/i1983e/i1983e.pdf

Fultz, A. K., Rex, S. M., Mazelin, A., McGarry, C., Brewer, B., Patterson, F., & Robson, S. (2021). Examining fruit and vegetable intake in low-income older adults using the Veggie Meter®. *Nutr Health*, 2601060211022275. doi:10.1177/02601060211022275

Gemming, L., Jiang, Y., Swinburn, B., Utter, J., & Mhurchu, C. N. (2014). Under-reporting remains a key limitation of self-reported dietary intake: an analysis of the 2008/09 New Zealand Adult Nutrition Survey. *European Journal of Clinical Nutrition, 68*(2), 259-264. doi:10.1038/ejcn.2013.242

Gibson, R., & Ferguson, E. L. (1999). *An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries*. Washington, D.C. : International Life Sciences Institute.

Gibson, R. S. (2005). *Principles of nutritional assessment* (2nd ed ed.): Oxford University Press.

Gibson, R. S., Charrondiere, U. R., & Bell, W. (2017). Measurement Errors in Dietary Assessment Using Self-Reported 24-Hour Recalls in Low-Income Countries and Strategies for Their Prevention. *Advances in nutrition (Bethesda, Md.), 8*(6), 980-991. doi:10.3945/an.117.016980

Gibson, R. S., Ferguson, Elaine L. (2008). *An Interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries*. Washington, D.C, Cali, Colombia International Food Polocy Research Institute (IFPRI), International Center for Tropical Agriculture (CIAT).

Glover, M., Wong, S. F., Taylor, R. W., Derraik, J. G. B., Fa'alili-Fidow, J., Morton, S. M., & Cutfield, W. S. (2019). The Complexity of Food Provisioning Decisions by Māori Caregivers to Ensure the Happiness and Health of Their Children. *Nutrients, 11*(5), 994. doi:10.3390/nu11050994

Graham, R., Hodgetts, D., Stolte, O. E. E., & Chamberlain, K. (2018). Food insecurity in urban New Zealand. The case of the Kopa family. *Journal of Poverty, -online*, 1-19. doi:DOI:10.1080/10875549.2017.1419533

Gregorič, M., Zdešar Kotnik, K., Pigac, I., & Gabrijelčič Blenkuš, M. (2019). A Web-Based 24-H Dietary Recall Could Be a Valid Tool for the Indicative Assessment of Dietary Intake in Older Adults Living in Slovenia. *Nutrients, 11*(9), 2234. doi:10.3390/nu11092234

Hartmann, Y., Botelho, R. B. A., Akutsu, R. d. C. C. d. A., & Puppin Zandonadi, R. (2018). Consumption of Fruits and Vegetables by Low-Income Brazilian Undergraduate Students: A Cross-Sectional Study. *Nutrients, 10*(8), 1121. doi:10.3390/nu10081121

He, F. J., Nowson, C. A., Lucas, M., & MacGregor, G. A. (2007). Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. *J Hum Hypertens, 21*(9), 717-728. doi:10.1038/sj.jhh.1002212

Health, M. o. (2003). *Nutrition and the burden of disease: New Zealand 1997-2011*. (17). Wellington: New Zealand: Ministry of Health

Hill, C. M., Paschall, M. J., O'Brien, D. M., & Bersamin, A. (2021). Characterizing Vegetable and Fruit Intake in a Remote Alaska Native Community Using Reflection Spectroscopy and 24-Hour Recalls. *Journal of Nutrition Education & Behavior, 53*(8), 712-718. Retrieved from http://ezproxy.massey.ac.nz/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,cookie,url,uid&db=s3h&AN=151608192&site=eds-live&scope=site&authtype=sso&custid=s3027306

Holmes, B., Dick, K., & Nelson, M. (2008). A comparison of four dietary assessment methods in materially deprived households in England. *Public Health Nutrition, 11*(5), 444-456. doi:10.1017/S1368980007000559

Hosseinpoor, A. R., Bergen, N., Kunst, A., Harper, S., Guthold, R., Rekve, D., . . . Chatterji, S. (2012). Socioeconomic inequalities in risk factors for non communicable diseases in low-income and middle-income countries: results from the World Health Survey. *BMC Public Health, 12*(1), 912. doi:10.1186/1471-2458-12-912

Jaeger, S. R., & Bava, C. M. (2009). Fruit consumption among people living in a high deprivation New Zealand neighbourhood. *Aust N Z J Public Health, 33*(5), 471-476. doi:10.1111/j.1753-6405.2009.00432.x

Jahns, L., Johnson, L. K., Conrad, Z., Bukowski, M., Raatz, S. K., Jilcott Pitts, S., . . . Gellermann, W. (2019). Concurrent validity of skin carotenoid status as a concentration biomarker of vegetable and fruit intake compared to multiple 24-h recalls and plasma carotenoid concentrations across one year: a cohort study. *Nutr J, 18*(1), 78. doi:10.1186/s12937-019-0500-0

Jilcott Pitts, S. B., Jahns, L., Wu, Q., Moran, N. E., Bell, R. A., Truesdale, K. P., & Laska, M. N. (2018). A non-invasive assessment of skin carotenoid status through reflection spectroscopy is a feasible, reliable and potentially valid measure of fruit and vegetable consumption in a diverse community sample. *Public Health Nutrition, 21*(9), 1664-1670. doi:10.1017/S136898001700430X

Jobarteh, M. L., McCrory, M. A., Lo, B., Sun, M., Sazonov, E., Anderson, A. K., . . . Frost, G. (2020). Development and Validation of an Objective, Passive Dietary Assessment Method for Estimating Food and Nutrient Intake in Households in Low- and Middle-Income Countries: A Study Protocol. *Current developments in nutrition, 4*(2), nzaa020. doi:10.1093/cdn/nzaa020

Jones, R., Wham, C., & Burlingame, B. (2019). New Zealand's Food System Is Unsustainable: A Survey of the Divergent Attitudes of Agriculture, Environment, and Health Sector Professionals Towards Eating Guidelines. *Frontiers in nutrition, 6*. doi:10.3389/fnut.2019.00099

Kaaks, R. J. (1997). Biochemical markers as additional measurements in studies of the accuracy of dietary questionnaire measurements: conceptual issues. *The American Journal of Clinical Nutrition, 65*(4), 1232S-1239S. doi:10.1093/ajcn/65.4.1232S

Kehoe, S. H., Dhurde, V., Bhaise, S., Kale, R., Kumaran, K., Gelli, A., . . . Fall, C. H. D. (2019). Barriers and Facilitators to Fruit and Vegetable Consumption Among Rural Indian Women of Reproductive Age. *Food and Nutrition Bulletin, 40*(1), 87-98. doi:10.1177/0379572118816459

Kendall, C. W. C., Esfahani, A., & Jenkins, D. J. A. (2010). The link between dietary fibre and human health. *Food Hydrocolloids, 24*(1), 42-48. doi:https://doi.org/10.1016/j.foodhyd.2009.08.002

Kim, D. J., & Holowaty, E. J. (2003). Brief, validated survey instruments for the measurement of fruit and vegetable intakes in adults: a review. *Preventive Medicine, 36*(4), 440-447. doi:https://doi.org/10.1016/S0091-7435(02)00040-3

Kira, G., Kira, A., & Pokaia, V. (2021). Access and consumption of fruit and vegetables for people living in a deprived neighborhood in New Zealand: a cross-sectional study. *Journal of Hunger & Environmental Nutrition*, 1-15. doi:10.1080/19320248.2021.1901820

Kirkpatrick, S. I., Guenther, P. M., Douglass, D., Zimmerman, T., Kahle, L. L., Atoloye, A., . . . Durward, C. (2019). The Provision of Assistance Does Not Substantially Impact the Accuracy of 24-Hour Dietary Recalls Completed Using the Automated Self-Administered 24-H Dietary Assessment Tool among Women with Low Incomes. *J Nutr, 149*(1), 114-122. doi:10.1093/jn/nxy207

Krieger, N. (2001). A glossary for social epidemiology. *Journal of Epidemiology and Community Health, 55*(10), 693-700. doi:10.1136/jech.55.10.693

Kruger, R., Schönfeldt, H. C., & Owen, J. H. (2008). Food-coping strategy index applied to a community of farm-worker households in South Africa. *Food Nutr Bull, 29*(1), 3-14. doi:10.1177/156482650802900101

Lanumata T, H. C., Signal L, Haretuku R, and Corrigan C. (2008). *Enhancing food security and physical activity for Māori, Pacfic and low income whānau/families research*. Retrieved from Wellington:

Lattimer, J. M., & Haub, M. D. (2010). Effects of dietary fiber and its components on metabolic health. *Nutrients, 2*(12), 1266-1289. doi:10.3390/nu2121266

Lins, I. L. L., Bueno, N. B., Grotti Clemente, A. P., Pfrimer, K., Sawaya, A. L., & de Menezes Toledo Florêncio, T. M. (2016). Energy Intake in Socially Vulnerable Women Living in Brazil: Assessment of the Accuracy of Two Methods of Dietary Intake Recording Using Doubly Labeled Water. *Journal of the Academy of Nutrition and Dietetics, 116*(10), 1560-1567. doi:https://doi.org/10.1016/j.jand.2016.02.023

Livingstone, M. B., & Black, A. E. (2003). Markers of the validity of reported energy intake. *J Nutr, 133 Suppl 3*, 895s-920s. doi:10.1093/jn/133.3.895S

Lorenzoni, G., Bottigliengo, D., Azzolina, D., & Gregori, D. (2019). Food Composition Impacts the Accuracy of Wearable Devices When Estimating Energy Intake from Energy-Dense Food. *Nutrients, 11*(5), 1170. doi:10.3390/nu11051170

Lyles, C. R., Wolf, M. S., Schillinger, D., Davis, T. C., Dewalt, D., Dahlke, A. R., . . . Seligman, H. K. (2013). Food insecurity in relation to changes in hemoglobin A1c, self-efficacy, and fruit/vegetable intake during a diabetes educational intervention. *Diabetes care, 36*(6), 1448-1453. doi:10.2337/dc12-1961

Mackay, S., Buch, T., Vandevijvere, S., Goodwin, R., Korohina, E., Funaki-Tahifote, M., . . . Swinburn, B. (2018). Cost and Affordability of Diets Modelled on Current Eating Patterns and on Dietary Guidelines, for New Zealand Total Population, Māori and Pacific Households. *International Journal of Environmental Research and Public Health, 15*(6), 1255. Retrieved from https://www.mdpi.com/1660-4601/15/6/1255

Mainvil, L. A., Horwath, C. C., McKenzie, J. E., & Lawson, R. (2011). Validation of brief instruments to measure adult fruit and vegetable consumption. *Appetite, 56*(1), 111-117. doi:10.1016/j.appet.2010.09.008

Martinelli, S., Acciai, F., Tasevska, N., & Ohri-Vachaspati, P. (2021). Using the Veggie Meter in Elementary Schools to Objectively Measure Fruit and Vegetable Intake: A Pilot Study. *Methods and Protocols, 4*(2), 33. Retrieved from https://www.mdpi.com/2409-9279/4/2/33

May, K., Jilcott Pitts, S., Stage, V. C., Kelley, C. J., Burkholder, S., Fang, X., . . . Lazorick, S. (2020). Use of the Veggie Meter® as a tool to objectively approximate fruit and vegetable intake among youth for evaluation of preschool and school-based interventions. *J Hum Nutr Diet, 33*(6), 869-875. doi:10.1111/jhn.12755

McKerchar, C., Bowers, S., Heta, C., Signal, L., & Matoe, L. (2015). Enhancing Māori food security using traditional kai. *Glob Health Promot, 22*(3), 15-24. doi:10.1177/1757975914543573

Mello, J. A., Gans, K. M., Risica, P. M., Kirtania, U., Strolla, L. O., & Fournier, L. (2010). How is food insecurity associated with dietary behaviors? An analysis with low-income, ethnically diverse participants in a nutrition intervention study. *Journal of the American Dietetic Association, 110*(12), 1906-1911. doi:10.1016/j.jada.2010.09.011

Ministry of Health. (2003). *Nutrition and the burden of disease: New Zealand 1997-2011*. (17). Wellington: New Zealand: Ministry of Health

Ministry of Health. (2014). Māori Health Statistics: Cardiovascular disease. Retrieved from https://www.health.govt.nz/our-work/populations/maori-health/tatau-kahukura-maori-health-statistics/nga-mana-hauora-tutohu-health-status-indicators/cardiovascular-disease#1

Ministry of Health. (2019a). Annual Update of Key Results 2018/19: New Zealand Health Survey.

Ministry of Health. (2019b). *Wai 2575 Māori health trends report*. Retrieved from Wellington: https://www.health.govt.nz/our-work/populations/maori-health/tatau-kahukura-maori-health-statistics/nga-mana-hauora-tutohu-health-status-indicators/diabetes

Ministry of Health. (2020). Annual update of key results 2019/20: New Zealand Health Survey.

Ministry of Health (2020). *Eating and Activity Guidelines for New Zealand Adults: New serving size advice* Wellington

Ministry of Health. (2021). New Zealand Health Survey Indicator: Meets vegetable and fruit intake guidelines (New Zealand Health Survey). Retrieved from https://minhealthnz.shinyapps.io/nz-health-survey-2017-20-regional-update/_w_ca5d1077/#!/compare-regions. shinyapps, from Ministry of Health https://minhealthnz.shinyapps.io/nz-health-survey-2017-20-regional-update/_w_ca5d1077/#!/compare-regions

Ministry of Health (2021a). New Zealand Health Survey: Eating 3+ servings of vegetables and 2+ servings of fruit per day for adults. from Ministry of Health

Ministry of Health (2021b). Obesity statistics.

Moeke-Pickering, T., Heitia, M., Heitia, S., Karapu, R., & Cote-Meek, S. (2015). *UNDERSTANDING MfORI FOOD SECURITY AND FOOD SOVEREIGNTY ISSUES IN WHAKATfNE*.

MRC, M. R. C. (2020). DAPA measurement toolkit: Dietary assessment. Retrieved from https://dapa-toolkit.mrc.ac.uk/diet/subjective-methods/24-hour-dietary-recall

National Health and Medical Council. (2013). *Australian Dietary Guidelines* Canberra: National Health and Medical Research Counci

National Institutes of Health (2022). Vitamin A and Carotenoids. Retrieved from https://ods.od.nih.gov/factsheets/VitaminA-Consumer/

Nour, M., Sui, Z., Grech, A., Rangan, A., McGeechan, K., & Allman-Farinelli, M. (2017). The fruit and vegetable intake of young Australian adults: a population perspective. *Public Health Nutrition, 20*(14), 2499-2512. doi:10.1017/S1368980017001124

O'Loughlin, G., Cullen, S. J., McGoldrick, A., O'Connor, S., Blain, R., O'Malley, S., & Warrington, G. D. (2013). Using a wearable camera to increase the accuracy of dietary analysis. *Am J Prev Med, 44*(3), 297-301. doi:10.1016/j.amepre.2012.11.007

Pezdirc, K., Hutchesson, M. J., Whitehead, R., Ozakinci, G., Perrett, D., & Collins, C. E. (2015). Fruit, Vegetable and Dietary Carotenoid Intakes Explain Variation in Skin-Color in Young Caucasian Women: A Cross-Sectional Study. *Nutrients, 7*(7), 5800-5815. doi:10.3390/nu7075251

Pienovi, L., Lara, M., Bustos, P., & Amigo, H. (2015). [Fruit and vegetable intake, and blood pressure. A population research]. *Arch Latinoam Nutr, 65*(1), 21-26.

Poslusna, K., Ruprich, J., Jakubikova, M., De Vries, J. H. M., & Van'T Veer, P. (2009). Misreporting of energy and micronutrient intake estimated by food records and 24hour recalls, control and adjustment methods in practice. *British Journal of Nutrition, 101*(SUPPL. 2), S73-S85. doi:10.1017/S0007114509990602

Public Health England (2018). *The Eatwell Guide. Helping you eat a healthy, balanced diet.* London: Public Health England

Radtke, M. D., Pitts, S. J., Jahns, L., Firnhaber, G. C., Loofbourrow, B. M., Zeng, A., & Scherr, R. E. (2020). Criterion-Related Validity of Spectroscopy-Based Skin Carotenoid Measurements as a Proxy for Fruit and Vegetable Intake: A Systematic Review. *Advances in nutrition (Bethesda, Md.), 11*(5), 1282-1299. doi:10.1093/advances/nmaa054

Rahiman, A. M. A. M., & Ab-Rahman.M.S. (2013). Carotenoids Concentration Detection Investigation: A Review of Current Status and Future Trend. *International Journal of Bioscience, Biochemistry and Bioinformatics, 3*(5), 466-472. doi:10.7763/IJBBB.2013.V3.257

Raper, N., Perloff, B., Ingwersen, L., Steinfeldt, L., & Anand, J. (2004). An overview of USDA's Dietary Intake Data System. *Journal of Food Composition and Analysis, 17*(3), 545-555. doi:https://doi.org/10.1016/j.jfca.2004.02.013

Reid, P., & Robson, B. (2007). Understanding Health Inequities. *Hauora: Maori Standards of Health IV. A Study of the Years 2000-2005, 4*.

Richter, A. (2021). *An investigation of the fruit and vegetable intake of Pacific and NZE women with different body composition profiles : a thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Nutrition and Dietetics, Massey University, Albany, New Zealand.* (Thesis). Massey University, Retrieved from https://ezproxy.massey.ac.nz/login?url=https://search.ebscohost.com/login.aspx?direct

=true&AuthType=sso&db=ir00033a&AN=massnz.10179.16719&site=eds-live&scope=site&authtype=sso&custid=s3027306
http://hdl.handle.net/10179/16719 Available from EBSCOhost Massey Research Online database.

Rock, C. L., Swendseid, M. E., Jacob, R. A., & McKee, R. W. (1992). Plasma Carotenoid Levels in Human Subjects Fed a Low Carotenoid Diet. *The Journal of Nutrition, 122*(1), 96-100. doi:10.1093/jn/122.1.96

Rush, E., Amoah, I., Diep, T., & Jalili-Moghaddam, S. (2020). Determinants and Suitability of Carotenoid Reflection Score as a Measure of Carotenoid Status. *Nutrients, 12*(1), 113. doi:10.3390/nu12010113

Rush, E., Savila, F. a., Jalili-Moghaddam, S., & Amoah, I. (2019). Vegetables: New Zealand Children Are Not Eating Enough. *Frontiers in nutrition, 5*, 134-134. doi:10.3389/fnut.2018.00134

Scarmo, S., Henebery, K., Peracchio, H., Cartmel, B., Lin, H., Ermakov, I. V., . . . Mayne, S. T. (2012). Skin carotenoid status measured by resonance Raman spectroscopy as a biomarker of fruit and vegetable intake in preschool children. *European Journal of Clinical Nutrition, 66*(5), 555-560. doi:10.1038/ejcn.2012.31

Schwingshackl, L., Hoffmann, G., Kalle-Uhlmann, T., Arregui, M., Buijsse, B., & Boeing, H. (2015). Fruit and Vegetable Consumption and Changes in Anthropometric Variables in Adult Populations: A Systematic Review and Meta-Analysis of Prospective Cohort Studies. *PLoS one, 10*(10), e0140846. doi:10.1371/journal.pone.0140846

Schwingshackl, L., Schwedhelm, C., Hoffmann, G., & Boeing, H. (2019). Potatoes and risk of chronic disease: a systematic review and dose-response meta-analysis. *European journal of nutrition, 58*(6), 2243-2251. doi:10.1007/s00394-018-1774-2

Seguin-Fowler, R. A., Hanson, K. L., Marshall, G. A., Belarmino, E. H., Jilcott Pitts, S. B., Kolodinsky, J., . . . Ammerman, A. (2021). Fruit and Vegetable Intake Assessed by Repeat 24 h Recalls, but Not by A Dietary Screener, Is Associated with Skin Carotenoid Measurements in Children. *Nutrients, 13*(3), 980. doi:10.3390/nu13030980

Seligman, H. K., Davis, T. C., Schillinger, D., & Wolf, M. S. (2010). Food insecurity is associated with hypoglycemia and poor diabetes self-management in a low-income sample with diabetes. *J Health Care Poor Underserved, 21*(4), 1227-1233. doi:10.1353/hpu.2010.0921

Seligman, H. K., Laraia, B. A., & Kushel, M. B. (2010). Food insecurity is associated with chronic disease among low-income NHANES participants. *J Nutr, 140*(2), 304-310. doi:10.3945/jn.109.112573

Shankar, S., Klassen, A. C., Garrett-Mayer, E., Houts, P. S., Wang, T., McCarthy, M., . . . Zhang, L. (2006). Evaluation of a nutrition education intervention for women residents of Washington, DC, public housing communities. *Health Education Research, 22*(3), 425-437. doi:10.1093/her/cyl092

Slavin, J. L., & Lloyd, B. (2012). Health benefits of fruits and vegetables. *Advances in nutrition (Bethesda, Md.), 3*(4), 506-516. doi:10.3945/an.112.002154

Smith-Warner, S. A., Elmer, P. J., Fosdick, L., Tharp, T. M., & Randall, B. (1997). Reliability and comparability of three dietary assessment methods for estimating fruit and vegetable intakes. *Epidemiology, 8*(2), 196-201. doi:10.1097/00001648-199703000-00013

St George, S. M., Van Horn, M. L., Lawman, H. G., & Wilson, D. K. (2016). Reliability of 24-Hour Dietary Recalls as a Measure of Diet in African-American Youth. *J Acad Nutr Diet, 116*(10), 1551-1559. doi:10.1016/j.jand.2016.05.011

Stahl, W., & Sies, H. (2005). Bioactivity and protective effects of natural carotenoids. *Biochim Biophys Acta, 1740*(2), 101-107. doi:10.1016/j.bbadis.2004.12.006

Stein, K., Mirosa, M., & Carter, L. (2018). Māori women leading local sustainable food systems. *AlterNative: An International Journal of Indigenous Peoples, 14*(2), 147-155. doi:10.1177/1177180117753168

Streppel, M. T., Ocké, M. C., Boshuizen, H. C., Kok, F. J., & Kromhout, D. (2008). Dietary fiber intake in relation to coronary heart disease and all-cause mortality over 40 y: the Zutphen Study. *The American Journal of Clinical Nutrition, 88*(4), 1119-1125. doi:10.1093/ajcn/88.4.1119

Subar, A. F., Thompson, F. E., Potischman, N., Forsyth, B. H., Buday, R., Richards, D., . . . Baranowski, T. (2007). Formative research of a quick list for an automated self-administered 24-hour dietary recall. *J Am Diet Assoc, 107*(6), 1002-1007. doi:10.1016/j.jada.2007.03.007

Subar, A. F., Thompson, F. E., Potischman, N., Forsyth, B. H., Buday, R., Richards, D., . . . Baranowski, T. (2007). Formative Research of a Quick List for an Automated Self-Administered 24-Hour Dietary Recall. *Journal of the American Dietetic Association, 107*(6), 1002-1007. doi:https://doi.org/10.1016/j.jada.2007.03.007

Swinburn, B., Dominick, C.H. and Vandevijvere, S. . (2014). *Benchmarking Food Environments: Experts' assessments of policy gaps and priorities for the New Zealand Government*. Retrieved from Auckland New Zealand:

The European Food Information Council (2006). The factors that influence our food choices.

Thompson, F. E., Kipnis, V., Subar, A. F., Krebs-Smith, S. M., Kahle, L. L., Midthune, D., . . . Schatzkin, A. (2000). Evaluation of 2 brief instruments and a food-frequency questionnaire to estimate daily number of servings of fruit and vegetables. *Am J Clin Nutr, 71*(6), 1503-1510. doi:10.1093/ajcn/71.6.1503

Thomson, C. A., & Ravia, J. (2011). A Systematic Review of Behavioral Interventions to Promote Intake of Fruit and Vegetables. *Journal of the American Dietetic Association, 111*(10), 1523-1535. doi:https://doi.org/10.1016/j.jada.2011.07.013

Tooze, J. A., Vitolins, M. Z., Smith, S. L., Arcury, T. A., Davis, C. C., Bell, R. A., . . . Quandt, S. A. (2007). High Levels of Low Energy Reporting on 24-Hour Recalls and Three Questionnaires in an Elderly Low-Socioeconomic Status Population1,2. *The Journal of Nutrition, 137*(5), 1286-1293. Retrieved from http://ezproxy.massey.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edsovi&AN=edsovi.01720559.200705000.00028&site=eds-live&scope=site

Tran, K. M., Johnson, R. K., Soultanakis, R. P., & Matthews, D. E. (2000). In-person vs Telephone-administered Multiple-pass 24-hour Recalls in Women: Validation with Doubly Labeled

Water. *Journal of the American Dietetic Association, 100*(7), 777-783. doi:10.1016/S0002-8223(00)00227-3
United States Department of Agriculture. (2014). *A series of systemactic reviews on the relationship between dietary patterns and health outcomes*. Retrieved from
University of Auckland (2018). Health geography and deprivation interactive maps IMD18 (Research). Retrieved from https://imdmap.auckland.ac.nz/viewdata/NZIMD2018_Single_animation_w_logos/atlas.html. https://imdmap.auckland.ac.nz/viewdata/NZIMD2018_Single_animation_w_logos/atlas.html
University of Otago, & Health, M. o. (2011). *A focus on nutrition: Key findings of the 2008/2009 New Zealand Adult Nutrition Survey*. Wellington, New Zealand Retrieved from https://www.health.govt.nz/publication/focus-nutrition-key-findings-2008-09-nz-adult-nutrition-survey
University of Otago; Ministry of Health. (2011). *Methodology Report for the 2008/09 New Zealand Adult Nutrition Survey*. Retrieved from Wellington:
USDA. (2020). *Dietary guidelines for Americans, 2020-2025*. Washington
Viriaere, H., & Miller, C. (2018). Living Indigenous Heritage: Planning for Māori Food Gardens in Aotearoa/New Zealand. *Planning Practice & Research, 33*(4), 409-425. doi:10.1080/02697459.2018.1519931
Vucic, V., Glibetic, M., Novakovic, R., Ngo, J., Ristic-Medic, D., Tepsic, J., . . . Gurinovic, M. (2009). Dietary assessment methods used for low-income populations in food consumption surveys: a literature review. *British Journal of Nutrition, 101*(S2), S95-S101. doi:10.1017/S0007114509990626
Wallace, T., Bailey, R., Blumberg, J., Burton-Freeman, B., Chen, O., Crowe-White, K., . . . Wang, D. (2019). Fruits, vegetables, and health: A comprehensive narrative, umbrella review of the science and recommendations for enhanced public policy to improve intake. *Critical Reviews in Food Science and Nutrition, 60*, 1-38. doi:10.1080/10408398.2019.1632258
Wang, D. D., Li, Y., Bhupathiraju, S. N., Rosner, B. A., Sun, Q., Giovannucci, E. L., . . . Hu, F. B. (2021). Fruit and Vegetable Intake and Mortality. *Circulation, 143*(17), 1642-1654. doi:doi:10.1161/CIRCULATIONAHA.120.048996
Wedick, N. M., Pan, A., Cassidy, A., Rimm, E. B., Sampson, L., Rosner, B., . . . van Dam, R. M. (2012). Dietary flavonoid intakes and risk of type 2 diabetes in US men and women. *The American Journal of Clinical Nutrition, 95*(4), 925-933. doi:10.3945/ajcn.111.028894
Whigham, L. D., & Redelfs, A. H. (2016). Inter-finger Variability and Other Influencing Factors for Using Reflectance Spectroscopy for Skin Carotenoid Detection. *The FASEB Journal, 30*(S1), 409.402-409.402. doi:https://doi.org/10.1096/fasebj.30.1_supplement.409.2
WHO/FAO. (2003). *Diet, nutrition and the prevention of chronic disease*. Retrieved from Geneva, Switzerland: Diet, nutrition and the prevention of chronic disease
Willows, N., Veugelers, P., Raine, K., & Kuhle, S. (2011). Associations between household food insecurity and health outcomes in the Aboriginal population (excluding reserves). *Health Rep, 22*(2), 15-20.

Yanek, L. R., Moy, T. F., RaqueÑO, J. V., & Becker, D. M. (2000). Comparison of the Effectiveness of a Telephone 24-hour Dietary Recall Method vs an In-person Method among Urban African-American Women. *Journal of the American Dietetic Association, 100*(10), 1172-1177. doi:https://doi.org/10.1016/S0002-8223(00)00341-2

Yeh, M.-C., Ickes, S. B., Lowenstein, L. M., Shuval, K., Ammerman, A. S., Farris, R., & Katz, D. L. (2008). Understanding barriers and facilitators of fruit and vegetable consumption among a diverse multi-ethnic population in the USA. *Health Promotion International, 23*(1), 42-51. doi:10.1093/heapro/dam044

Zhan, J., Liu, Y. J., Cai, L. B., Xu, F. R., Xie, T., & He, Q. Q. (2017). Fruit and vegetable consumption and risk of cardiovascular disease: A meta-analysis of prospective cohort studies. *Crit Rev Food Sci Nutr, 57*(8), 1650-1663. doi:10.1080/10408398.2015.1008980

Appendix A: Supplementary Methods

Supplementary Table 1

The finalised 24-hour food recall template used in this study

24-hour food recall form

<table>
<tr><td colspan="4">Interviewer:
Date & Time:
Day Food Eaten:</td><td colspan="3">Subject ID:
In person: ☐ Telephone:☐ Video-call: ☐</td></tr>
<tr><td>Quick List</td><td>Time</td><td>Place Eaten</td><td>Description of food/drink
Include brands, sauces, oil, dressings, toppings, recipes</td><td>Amount Eaten
(unit, measure, weight /volume)</td><td>Dinner-ware</td><td>Cooking method</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Was it a feast day? Yes ☐ No ☐
Was food intake usual ? Yes ☐ No ☐
If yes, how was it unusual?</td><td colspan="3">Probe for sickness: Yes ☐ No ☐
If yes, did sickness affect appetite ? : Yes ☐ No ☐
If yes, how ? Increase ☐ Decrease☐</td></tr>
</table>

Supplementary Table 2

The 24-hour Fruit and Vegetable Diversity used in this study

24-hour Fruit and Vegetable Diversity

Have you in the past 24 hours eaten any of the following fruit and vegetables:		Yes	No
Starchy Vegetables			
Potato	Riwai		
Kumara / sweet potato	Kumara		
Corn	Konga		
Taro	Taro		
Beetroot	Rengokura		
Vegetables	**Hua Whenua**		
Carrot	Kareti		
Cabbage	Kapeti		
Silver-beet	Korare		
Watercress	Kowhitiwhiti		
Beans	Pini		
Broccoli	Poroki		
Cauliflower	Kareparaoa		
Celery	Herewi		
Squash	Komokomo		
Onion	Aniana		
Tomato	Tomato		
Spinach	Rengamutu		
Puha	Puha		
Pumpkin	Paukena		
Peas	Pi		
Lettuce	rērihi		
Fruit			
Apples	Aporo		
Banana	Panana		
Pears (fresh or tinned)	Pea		
Oranges	Arani		
Mandarins			
Feijoa			
Apricots (fresh or tinned)	Aperekoti		
Peaches (Fresh or tinned)	Piti		
Plum	Paramu		
Kiwifruit			
Grapes	Kerepi		
Watermelon	Merengi		
Pineapple	paināporo		
Juice			
Apple juice			
Orange Juice			
Mixed Juice (Tropical, mango, pineapple)			

Supplementary Table 3

The improved and updated 24-hour Diet Diversity Questionnaire

24-hour Diet Diversity Questionnaire

Have you in the past 24 hours eaten any of the following fruit and vegetables:		Yes	No
Starchy Vegetables			
Potato (Boiled, roasted, air-fried, pan-fried, microwaved)	Riwai		
Deep-fried chips (excludes packet of crisps)	Tītipi		
Kumara / sweet potato (excludes packet of crisps)	Kumara		
Corn	Konga		
Taro	Taro		
Beetroot	Rengokura		
Vegetables **- Hua Whenua**			
Carrot	Kareti		
Cabbage (savoy, red cabbage, napa, bok-choy)	Kapeti		
Silver-beet	Korare		
Watercress	Kowhitiwhiti		
Beans (green waxy beans, snap-beans, snow-peas)	Pini		
Broccoli	Poroki		
Capsicum	Rapikama		
Cauliflower	Kareparaoa		
Celery	Herewi		
Squash	Komokomo		
Onion	Aniana		
Mushrooms	Harore		
Tomato (excludes ketchup)	Tomato		
Spinach	Rengamutu		
Puha	Puha		
Pumpkin	Paukena		
Peas	Pi		
Lettuce	Rērihi		
Avocado	Rahopūru		
Other Vegetable – specify:			
Fruit (Fresh, tinned, frozen only)			
Apple	Aporo		
Banana	Panana		
Berries (Fresh, tinned, frozen, exclude jam and fruit-flavoured sweets, pastries and ice-cream)			
Pears	Pea		
Oranges	Arani		
Mandarin			
Feijoa			
Apricots	Aperekoti		
Peaches	Piti		
Plum	Paramu		
Kiwifruit			
Grapes	Kerepi		
Watermelon	Merengi		
Pineapple	Paināporo		
Dried Fruit -specify:	Karani		
Other fruit -specify:			
Juice (excludes cordials/fruit-flavoured soda)			
Store-bought Juice (e.g., Just Juice, McCoy)			
Homemade smoothies (TANK, homemade)			

Supplementary Table 4

Edible portion percentages of fruit and vegetables

APPROXIMATE YIELDS OF FRUITS & VEGETABLES

APPROX. WGT/EA	ITEM	YIELD %	APPROX. WGT/EA	ITEM	YIELD %
2# ea	Anise	75		Melons:	
	Apples	76		Cantaloupe	50
	Apricots	94		Casaba	50
	Artichokes	48		Cranshaw	50
	Asparagus	56		Honeydew, no rind	60
	Avocado	75		Watermelon, flesh	46
.44# ea	Bananas	68		Mushrooms	97
	Beans, green/wax	88		Mustard Greens	68
	Beans, lima, in shell	40		Nectarines	86
	Beets, no tops	76		Okra	78
	Beets, with tops	49	.33# bu	Onions, green (10-12)	60
	Beet greens	56		Onions, large	89
	Blackberries	92		Orange sections	70
	Blueberries	92	.33# bu	Parsley	76
1.5# bu	Broccoli	61		Parsnips	85
	Brussels sprouts	74		Peaches	76
2.5# ea	Cabbage, green	79		Pears	78
	Cantaloupe, no rind	50		Peas, green, in the shell	38
	Carrots, no tops	82	.33# ea	Peppers, green	82
	Carrots, with tops	60	.19# ea	Peppers, fryers	85
2# head	Cauliflower	45		Persimmons	82
2# bu	Celery	75	4# ea	Pineapple	52
	Celery root (celeriac)	75		Plums, pitted	85
	Chard	77		Pomegranates	54
26 oz ea	Coconut	53		Potatoes, red	81
	Collards			Potatoes, chef	85
.58# ea	Cucumbers	95		Potatoes, sweet	80
1.25# ea	Eggplant	81		Radishes, with tops	63
	Endive, chicory, escarole	74		Radishes, no tops	85
	Figs	82		Raspberries	97
	Fruit for juice*			Rhubarb, no leaves	86
16 oz	Grapefruit	45*	3# ea	Rutabagas	85
3.5 oz	Lemon	45*		Salsify	64
2.2 oz	Lime	35*	.03# ea	Shallots	89
6.6 oz	Oranges, Fla.	50*		Spinach	74
.125# ea	Garlic bulb (10-12 cloves)	87		Squash:	
	Grapefruit sections	47	.83# ea	Acorn	78
	Grapes, seedless	94	1.8# ea	Butternut	52
	Kale	74		Hubbard	66
	Kohlrabi	55	.36# ea	Yellow	95
.75# bu	Leeks	52	.58# ea	Zucchini	95
2.25# head	Lettuce, iceberg	74		Strawberries	87
	Lettuce, leaf	67			

*** the yield percentages of producing juice.**

Retrieved from The Culinary Institute of America's, 2016. "Educator lesson plan – Kitchen calculations".

Supplementary Table 5

Groupings of fruit and vegetables

	Vegetable	
AV	Allium Vegetables	Onion, leek, spring onion, shallots
CV	Cruciferous Vegetables	Broccoli, cabbage, cauliflower, cucumber, kale, bok choy, turnip, brussel sprouts
G, VA,V	Green, Vitamin A rich Vegetables	Puha, watercress, spinach, silver-beet, lettuce, taro leaves, courgettes
Y, VA,V	Yellow, Vitamin A rich vegetables	Carrot, capsicum, kumara, pumpkin
NSV	Non-starchy vegetables	Green beans, celery, mushrooms, asparagus, mung beans, eggplant, artichoke
SV	Starchy vegetables	Potato (including fries), kumara, sweet potato, corn, taro, cassava, breadfruit
T	Tomatoes	Fresh, canned, cooked
VCS	Vegetables contributing to starch	Peas, beetroot, pumpkin, squash, vegetable mix (e.g., corn, peas, carrots).
	Fruit	
VA F	Vitamin A, Fruit	Mandarin, orange, kiwifruit, grapefruit, lemon, lime
VC, F	Vitamin C, Fruit	Apricot, plum, watermelon, mango, persimmon, tamarillo, gooseberry, cantaloupe, cherries
OF,F	Other fruit, Fruit	Apple, banana, grape, feijoa, pear, peach, pineapple, guava, papaya, lychee, passionfruit, dates, coconut
FJ F	Fruit Juice, Fruit	Apple, orange, mixed (e.g., tropical)
BF	Berries fruit	Strawberry, blueberry, raspberry
DF	Dried Fruit	Cranberries, raisins, dried apricots, dried figs

Full version of the training guide and toolkit is available on request.

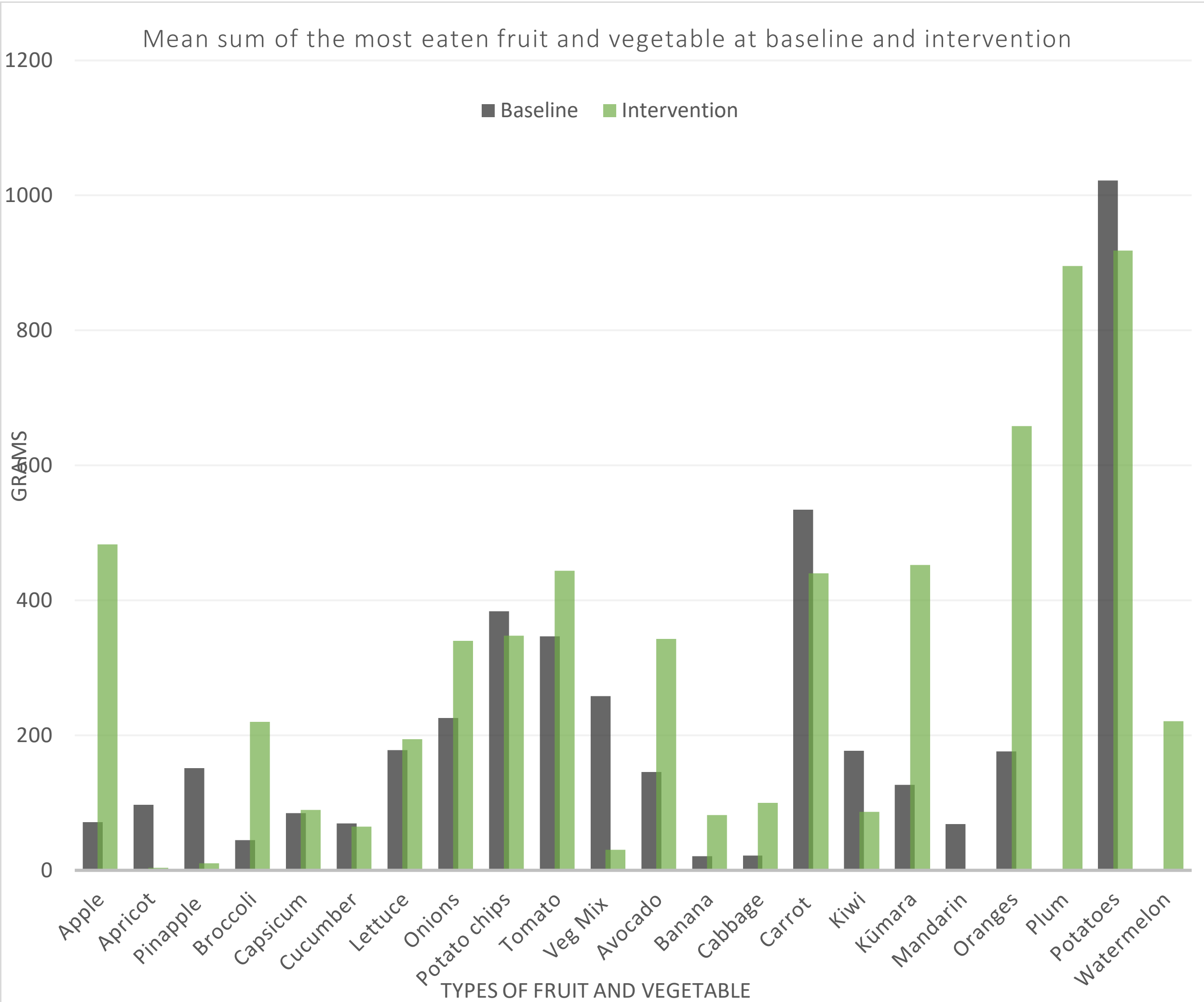
Supplementary Figure 1 *An example from the portion size booklet*

Kia Ora (Participant's name).
I am here today to carry out … Is this a good time to talk?

To briefly explain, … I'm going to ask you a series of questions about all the meals and snacks you had from the time that you woke up until the time that you went to bed yesterday…

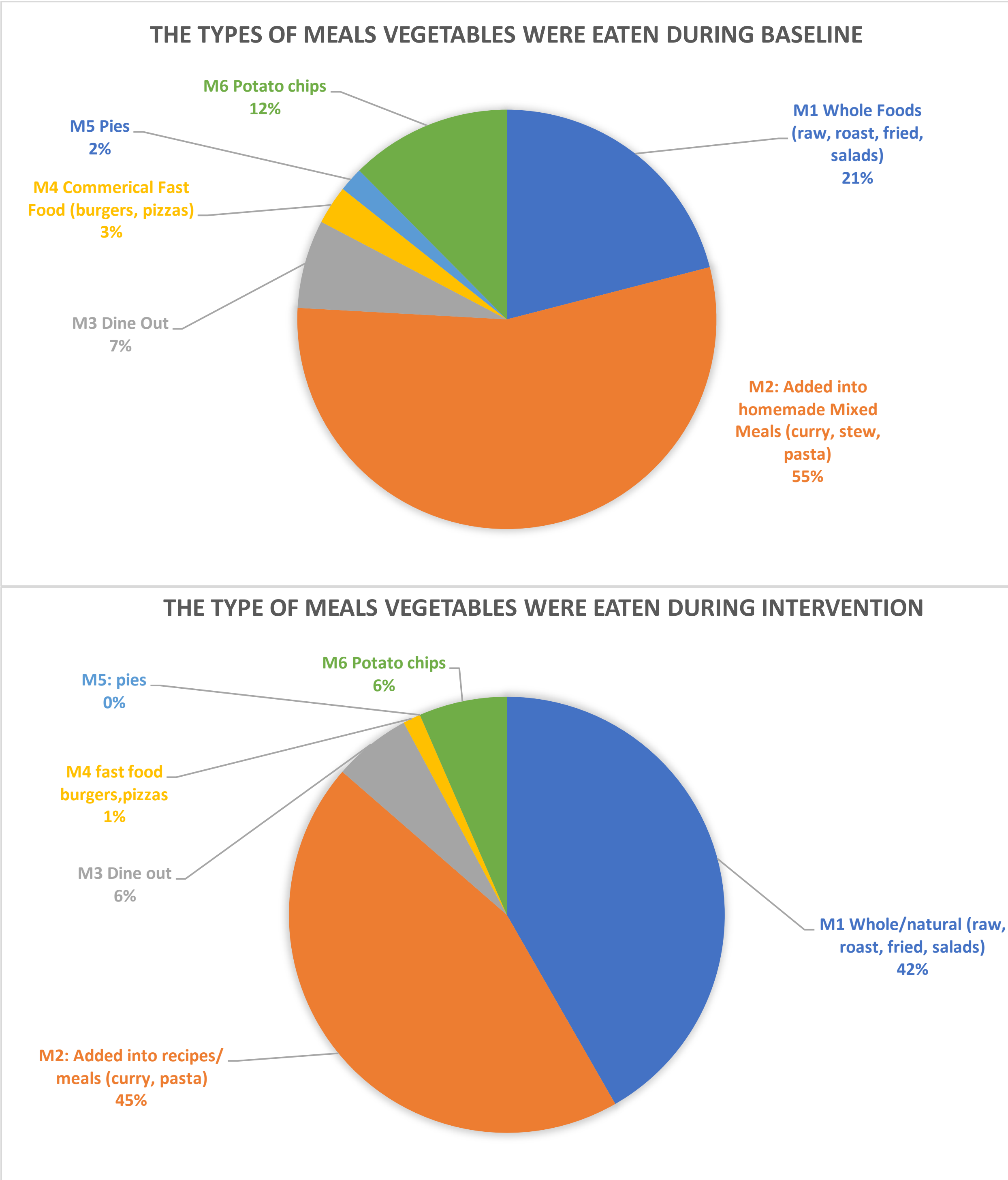
Supplementary Figure 2 *An example of the script for conducting a 24-hour food recall and training manual*

Appendix B: Supplementary Results



The fruit and vegetables given in the box in this chart include apples, broccoli, onions, cabbage, carrot, kūmara, oranges, plums, potatoes

Supplementary Figure 1 *The top 22 most eaten FV across the study, calculated by the sum of participant's mean intake*



Supplementary Figure 2 *The types of meals where the vegetables were consumed at baseline and intervention*

Supplementary Table 1

The Veggie Meter ® scores difference between smokers and non-smokers over the study period

	Baseline Mean ± SD	Intervention Mean ± SD	*p* value
Non-smokers (n = 5)	179 ± 169	255 ± 76	0.373 [d]
Smokers (n = 6)	208 ± 52	218 ± 69	0.407 [d]
	p = 0.726 [i]	p = 0.429 [i]	

One participant was missing a Veggie Meter score at baseline, hence only 11 participants were valid for analysis
d= *p* value was tested using a dependent paired sampled t-test
i = *p* value was tested using an independent t-test