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The Feasibility, Validity and Reliability of a Modified 24-hour Multiple Pass Dietary Recall to Assess Fruit and Vegetable Intake in New Zealand Children

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Abstract

Background

Adequate intake of fruits and vegetables (F/V) is crucial for children's growth, development, and health. Despite this, many New Zealand children do not meet recommended F/V intake levels. The validity and reliability of a modified 24-hour multiple pass recall (MPR) and alternative tools such as the Veggie Meter® (VM®) for measuring skin-carotenoid scores (SCS) as a biomarker of F/V intake in children remain unexplored.

Aims

To establish the feasibility, validity and reliability of the modified 24-hour MPR for the evaluation of carotenoid and fruit and vegetable intake against weighed food diaries in 9 to 13-year-old school children living in Auckland. To estimate the reliability of the VM® as a tool to measure chronic skin carotenoid levels.

Methods

Thirty-two children (20 boys, 12 girls) participated in this study. Over a one-to-three week period, F/V intake was assessed using a modified 24-hour MPR (child-reported, weighed food diaries (parent-reported), and SCS measured by the VM®. Validity was evaluated by comparing the modified 24-hour MPR to weighed food diaries as the criterion. Reliability of the modified 24-hour MPR F/V servings were determined from raw arithmetic difference, while reliability of the modified 24-hour MPR carotenoid intake ($\mu\text{g}/\text{d}$) was expressed as a ratio. Inter-day reliability of the modified 24-hour MPR and the VM® SCS reliability were estimated using various metrics.

Results

Children did not meet recommended F/V intake levels based on both the modified 24-hour MPR (1.31 fruit serves; 2.00 vegetable serves) and weighed food diaries (1.26 fruit serves; 1.87 vegetable serves). Boys had higher F/V and carotenoid intakes, while girls had slightly higher SCS. The modified 24-hour MPR demonstrated significant bias and poor reliability for estimating F/V and carotenoid intake. In contrast, the VM® showed good reliability with low variability and excellent intraclass correlation coefficient (ICC).

Conclusions

The modified 24-hour MPR was valid but unreliable for measuring F/V intake in New Zealand children. The VM[®] was found to provide a reliable measure of carotenoid intake over a chronic time.

Key words: “Dietary intake assessment”, “24-hour MPR”, “24-hour dietary recall”, “weighed food diary”, “fruit and vegetable”, “Veggie Meter[®]”, “validity”, “reliability”, “carotenoid”, and “children”

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The approval for this research has been obtained from the appropriate University Ethics Committee for the experiments described in this thesis.

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List of Abbreviations

BMI	Body Mass Index
CV	Coefficient of Variation
FFQ	Food Frequency Questionnaire
F/V	Fruit and Vegetables
ICC	Intraclass Correlation Coefficient
MUHEC	Massey University Human Ethics Committee
MELAA	Middle Eastern, Latin American, African
MPR	Multiple Pass Recall
NSLP	National School Lunch Program
NCDs	Noncommunicable diseases
RS	Reflection Spectroscopy
RRS	Resonance Raman Spectroscopy
SPAN	School Physical Activity and Nutrition
STEAM	Science, Technology, Engineering, Arts and Maths
SCS	Skin Carotenoid Score
TEE	Typical Error of Estimate
VM®	Veggie Meter®

Chapter 1

1.0 Introduction

1.1 Background

Diet plays an essential role in the growth and cognitive development of children (WHO, 2020). Adequate nutrition encourages a healthy lifestyle as it decreases the risk of becoming overweight or obese, and developing non-communicable diseases (NCDs) in the future (WHO, 2020). Fruit and vegetables (F/V) are an important aspect of the diet as they contain crucial nutrients which contribute to the growth and development of children. However, the 2022/23 New Zealand health surveys revealed that less than 5% of children met the F/V daily recommendation (Ministry of Health, 2023b). Specifically, 5.4% of children met the vegetable recommendation, while 70.9% met the fruit recommendation (Ministry of Health, 2023b). Inadequate consumption of F/V can increase the risk of NCDs, such as heart disease and some cancers (WHO, 2023).

Eating an adequate amount of F/V and making other healthy food choices can be affected by factors such as environment, income, and education. A study conducted in New Zealand discovered that supermarkets in deprived areas had more shelf space dedicated to unhealthy foods when compared to supermarkets in less deprived areas (Vandevijvere et al., 2018). Thus, influencing individuals to choose less nutritious options (Vandevijvere et al., 2018). Low socioeconomic environments also have an increased number of takeaways compared to less deprived areas, and this increased accessibility (Sushil et al., 2017). Low socioeconomic areas correlate with low income and food insecurity (Pannekoek & Rea, 2019). 21.5% of children who are raised in a food-insecure household in New Zealand have an increased risk of being overweight or obese (Greenwell & Grant, 2022). Low incomes may require parents to buy energy-dense foods as they tend to be cheaper than nutrient-dense foods. Studies have found that children who come from low-income families are more likely to have parents who lack schooling and education (Burkett, 2014). A lack of education may impact knowledge on healthy eating and influence the choices made.

In New Zealand, disparities in health outcomes, particularly among Māori and Pacific populations, are influenced by environment, income and educational inequities. These factors affect food choices. Māori and Pacific populations are seen to have poorer health outcomes, the 2022/23 New Zealand health survey found that Pacific children had the highest prevalence of obesity, followed by Māori children (Ministry of Health, 2023b). These groups also experience higher rates of poverty and increased food insecurity (Carter et al., 2010).

Carotenoids are a form of vitamin A called provitamin A, sourced from plants (Raymond & Morrow, 2021). They provide colour to F/V the darker the colour, the higher the content of carotenoids (Raymond & Morrow, 2021). Due to the high content of carotenoids in F/V they are used to assess F/V intake in individuals (Burrows et al., 2015). Carotenoids can be measured using a non-invasive device, which measures skin-carotenoid concentration via reflection spectroscopy (Rush & Bezzant, 2019). The score from the test reflects F/V intake of the individual. This is then evaluated against the dietary intake. Methods to measure dietary intake are the modified 24-hour multiple pass recall (MPR) and weighed food diaries.

A 24-hour MPR consists of a trained researcher interviewing an individual about their food and beverage intake over the last 24 hours. This method is memory-dependent, which influences the accuracy of the dietary information.

Weighed food diaries are completed by individuals weighing the food and beverages consumed as well as recording further details such as the brand name, cooking method, photo of the meal, and time and place the meal was eaten. This method can burden some people as it is an extra thing to complete during mealtimes.

Currently in New Zealand, no studies have examined the use of the VM[®] on children. This study will, therefore, provide novel insight into whether the VM[®] is a feasible method to measure F/V intake in children. Consequently, this may promote wider use of the VM[®] in such populations for future research.

Modified 24-hour MPRs have not been used in conjunction with weighed food diaries and the VM® to validate the accuracy and feasibility of estimating F/V intake in children. By validating the modified 24-hour MPR against weighed food diaries, this study will help identify whether the modified 24-hour MPRs are a valid and reliable method to use to assess F/V intake in children in future research, such as evaluating public health nutrition interventions in New Zealand children.

1.2 Purpose of the study

A child's diet is important, and a validated dietary intake tool must be available to measure aspects of the diet, such as F/V intake. The last national nutrition survey on children in New Zealand was completed in 2002 (Parnell et al., 2003), rendering the data outdated by more than 20 years. The supply of food has changed, and new food trends have emerged which would impact the diet patterns of children today. For example, F/V are more expensive than they used to be in 2002, this may impact the amount of produce families buy, resulting in children eating less. A more recent survey would indicate what food trends children follow, what their diets look like, what their diets lack and what is adequate. This study aimed to determine if a modified 24-hour MPR can be used as an accurate, reliable, and feasible method to assess F/V intake and evaluate carotenoid concentration in children for future studies.

1.3 Hypotheses

The modified 24-hour MPR will provide a valid and reliable measure of carotenoid intake in children aged 9–13 years.

1.4 Aims

To establish the feasibility, validity and reliability of the modified 24-hour MPR for the evaluation of carotenoid and fruit and vegetable intake against weighed food diaries in 9 to 13-year-old school children living in Auckland. To estimate the reliability of the VM® as a tool to measure chronic skin carotenoid levels.

1.5 Objectives

1. To compare the validity and reliability of the modified 24-hour MPR compared to weighed food diaries.
2. To determine the carotenoid intake of children.
3. To compare Veggie Meter® (VM®) skin-carotenoid score (SCS) to the modified 24-hour MPR and the weighed food diary's estimated fruit and vegetable intake.

1.6 Research Structure

This thesis has been laid out in four chapters. The first chapter introduces the topic of carotenoids and methods to measure dietary intake. The second chapter is the literature review, which looks at F/V intake in New Zealand children, the types and limitations of different dietary intake assessments, carotenoid and skin-carotenoid measurements, the validity of the VM® and dietary assessments, and lastly statistical approaches to determine validity and reliability. Chapter three is presented as a manuscript that outlines an abstract, introduction, methodology, results, discussion, strengths and limitations, and a conclusion. The final chapter discusses a brief overview of this study, the main findings, where future research is required, and the strengths and limitations. It concludes with recommendations from this study.

1.7 Research Contributions

Research team	Contribution to this thesis
Miss Varshika Patel	Primary author and researcher of this thesis. Responsible for recruiting participants, data collection, data entry, statistical analysis, interpretation of results, and writing and editing this thesis.
Prof. David Rowlands	Main supervisor, assisted with developing the modified 24-hour MPR, with the ethics application, and statistical analysis. Provided feedback on the entire thesis process. Funding applications and overall project supervision.
Prof. Carol Wham	Co-supervisor, assisted with developing the modified 24-hour MPR, with the ethics application, and training the research assistants.

Prof. Elain Rush	Provided the Veggie Meter® for this study.
Mrs Harshani Perera	Lead investigator for the main study. Responsible for the concept and research design, development of the modified 24-hour MPR, the Massey University ethics application, development of the study information sheet, and recruitment. Schools and participant recruitment and liaison.
Miss Alex Murphy	Assisted with data collection and data entry.
Ms Sarah McArley	Assisted with data entry.

Chapter 2

2.0 Review of Literature

2.1 Fruit and vegetable intake in New Zealand children

Fruit and vegetables are a crucial aspect of a healthy diet. The World Health Organisation claims that a diet low in F/V increases the risk of noncommunicable diseases, such as heart disease, cancer, type 2 diabetes and chronic respiratory disease (WHO, 2023). Fruit and vegetables are abundant in nutrients such as vitamins A, C, and E and are high in fibre, both soluble and insoluble fibre. Soluble fibre forms a gel-like consistency in the body which binds with short-chain fatty acids (Soliman, 2019). This process decreases total cholesterol in the body, particularly, LDL-cholesterol, which decreases the risk of cardiovascular disease (Soliman, 2019). The intake of F/V has also been shown to reduce the risk of some cancers, becoming overweight or obese, lower blood pressure, and help maintain gut health (Pem & Jeewon, 2015). Adequate intake of F/V aids with the growth and development of children (Rush et al., 2019). New Zealand's recommendation of daily vegetable intake for 9 to 13-year-old children is between 5-5.5 servings a day and at least two servings of fruit a day (Ministry of Health, 2023a). According to the 2022/23 New Zealand Health Survey, 70.9% of children aged 2-14 years old met the recommended servings of fruits, while only 5.4% of children met the recommended servings of vegetables; together, only 4.9% of New Zealand children were meeting the daily requirement for F/V (Ministry of Health, 2023b).

2.2 Barriers to fruit and vegetable intake

Children are presented with multiple barriers to F/V consumption, which may explain the low intake among children in New Zealand. These barriers include environmental, social, economic and personal beliefs or preferences. Environmental barriers include the home, school, and external food environment. A study undertaken with 9 to 11-year-old children from Dunedin, New Zealand, found that children were more likely to have a poor diet if their parents diet quality was poor (Davison et al., 2017). This was attributed to the lack of autonomy children have at this age, as parents are the sole providers of food, therefore, children eat what is provided to them by their parents (Davison et al., 2017). This finding

indicated that parent modelling was important, and a poor diet in a child can reflect a poor parental diet (Davison et al., 2017).

School food environments also play an important role in children's food choices. Over 50% of school canteens in New Zealand provided their students with foods which are deemed occasional foods, such as pastries, sausage rolls, garlic bread, and cheese-filled meals (D'Souza et al., 2022). When such foods are available to children, they are more likely to choose low quality energy-dense foods over snacks such as F/V (D'Souza et al., 2022). Increased accessibility to low-quality, energy-dense, nutrient-poor foods means that children are more likely to make unhealthy food choices (D'Souza et al., 2022). This study also found that schools in lower socioeconomic areas were more likely to have a healthy eating policy and participate in programs, and this made for a healthy school environment, which encourages students to make healthy food choices (D'Souza et al., 2022). Only 38.5% of primary schools in this study had a policy (D'Souza et al., 2022).

Lastly, the external food environment includes stores such as dairies, supermarkets and takeaway shops. A study conducted in New Zealand assessing the retail food environments around schools found that 68.5% of urban schools had a convenience store within 800 m of the school, and 62% of urban schools had a takeaway shop within 800 m of the school (Vandevijvere et al., 2016). Furthermore, schools in low socioeconomic areas tend to have a higher number of takeaways compared to less deprived areas (Sushil et al., 2017). Another study on five schools found that 87.5% of students passed at least one food outlet on their way to school or home (Walton et al., 2009). Kids Cam NZ found that 22% of children who participated in the study visited a convenience store/dairy, and most of the children who visited the store-bought non-core (unhealthy) foods (McKerchar et al., 2020). The accessibility to unhealthy food environments increases the likelihood of children consuming such foods.

Economic factors can pose a barrier to F/V intake. Parents are the sole providers of children aged 9–13 therefore, economic factors can determine what parents can buy and provide for their children. Parents expressed that F/V were too expensive and was challenging to include fresh produce in their food budgets (Gerritsen et al., 2019). When F/V are compared to energy-dense, convenient, and easy-to-prepare foods, families are more likely to buy

nutrient-poor foods as they tend to be cheaper, fit the family's budget, and often provide more food for the family (Gerritsen et al., 2019). In households where money was a stressor, F/V intake was more likely to be lower than in households where money was not a stressor (Utter et al., 2012).

Exposure to food hardship in childhood was related to poor nutrition, higher intake of unhealthy foods, and lower intake of a variety of F/V (Gerritsen et al., 2021). A New Zealand survey on household food insecurity among children found that children who lived in a food-insecure household were more likely to have a lower F/V intake and a higher intake of fast food and fizzy drinks (Pannekoek & Rea, 2019). The cost of living has increased in New Zealand, household living costs has increased by 6.2% in the 12 months to the March 2024 quarter (Stats New Zealand, 2024c). Increased cost of living may impact the amount of F/Vs brought and consumed in a household (Stats New Zealand, 2024c).

The last factors that affect F/V intake are personal beliefs, preferences and social aspects. What children decide to eat depends on what they like and do not like. This can be impacted by parents' diets, peers' diets, current habits, media and advertising (Pillay et al., 2022). Social influence from peers also impacts children's food decisions, if a peer has a lunch box with high-energy foods, children may find it more socially acceptable to have similar lunch boxes (Pillay et al., 2022).

2.3 Dietary intake assessment — types and limitations

Dietary intake assessments are used to assess nutritional intake and adequacy. They are used in various settings, such as hospitals, clinics, and research facilities. The types of dietary intake assessment methods used are 24-hour MPRs, weighed food diaries, self-reported food diaries, and food frequency questionnaires (FFQ).

24-hour multiple pass recall (MPR) assesses the dietary intake of individuals over the last 24 hours. 24-hour MPR allows for the assessment of a range of foods, brands and preparation methods compared to other assessments such as a FFQ (Bailey, 2021). The 24-hour MPR consists of three passes. In the first pass, the researcher collects an uninterrupted quick list

of the child's food and drink intake. In the second pass, a detailed list of the child's food and drink intake is recorded. This includes specifics such as time, place, brand name, and amount, which can be aided by tools such as a food atlas and measuring equipment. The third pass consists of reviewing the food and drink intake with the child and parent to fill in any gaps and retrieve any recipes provided in the interviews. The 24-hour MPR can be completed by participants with physical disabilities (blindness or inability to write) as the interviewer asks and writes the questions and answers (Bailey, 2021). The 24-hour MPR does not require a high literacy level from the participant as the interviewer records the data (Bailey, 2021). A disadvantages of 24-hour MPR is that it relies on memory, which can result in inaccurate information (Ralph et al., 2011). Another disadvantage is that the 24-hour MPR is susceptible to under- or overreporting due to social desirability (Gemming et al., 2014; Ralph et al., 2011). The 24-hour MPR requires the training and labour of an interviewer, which can be costly in both time and money (Bailey, 2021).

Weighed food diaries are conducted by participants, where they record weights of the food, brand names, preparation methods, and sometimes photos of their meals. Weighed food diaries provide a precise indication of what an individual eats, how much, and their nutrient intake. This method relies less on memory, which reduces reporting inaccuracies (Ralph et al., 2011). A disadvantage of weighed food diaries is the high burden as participants are required to weigh and measure everything they eat or drink (Ralph et al., 2011). Another disadvantage is that participants may change their eating habits to make the process easier, e.g., they may not eat out as it is more difficult to record a meal that was not cooked by them (Ralph et al., 2011).

A self-reported food diary is when individuals record their food intake over a period, usually 3–7 days. Participants are not required to weigh or measure their foods and beverages, which makes this method easier than weighed food diaries (Ralph et al., 2011). This method relies less on memory (Ralph et al., 2011). The disadvantage include having to record everything that is consumed (Ralph et al., 2011). Individuals have also been seen to record their intake less thoroughly as the days go on (Ralph et al., 2011).

A FFQ is a questionnaire that aims to determine how often an individual has a type of food. A list of various foods such as meats, breads and dairy foods is provided, and individuals must select how often they have it in a week over a certain period, e.g., a month or a year. A FFQ is cheaper than a 24-hour MPR as individuals carry it out themselves (Bailey, 2021). FFQs can be created or adapted to best suit the user, for example, they can be developed to be nutrient-specific or population-specific (Ralph et al., 2011). A disadvantage of the FFQ is that it lacks detail (Bailey, 2021). Different types of foods, brands, specific measurements and preparation methods are not asked in a FFQ (Bailey, 2021). Participants must be physically able to complete a FFQ and they are also required to be literate (Bailey, 2021). Food frequency questionnaires rely on long-term memory of food intake, which increases inaccuracies in reporting (Ralph et al., 2011).

2.4 Carotenoids

Like any other nutrient, vitamin A plays an important role in the human body. These roles include eye health, bone growth, immunity, cell division and reproduction (Raymond & Morrow, 2021). Vitamin A is found in two main forms. The first form is preformed vitamin A, which is found in animal foods such as liver and milk and is absorbed in the body as retinol (Raymond & Morrow, 2021). The second form of vitamin A is provitamin A which is called carotenoids, and this is found in plants. (Raymond & Morrow, 2021). They provide colour to F/V, the darker the colour, the higher the content of carotenoids (Raymond & Morrow, 2021). The common carotenoids are β -carotene, α -carotene, and β -cryptoxanthin (Raymond & Morrow, 2021). β -carotene is most efficiently converted to retinol (Raymond & Morrow, 2021). F/V intake can be assessed through carotenoid concentration due to their abundance of carotenoids (Burrows et al., 2015). Carotenoid concentration is determined through blood tests, dermal biopsy and skin reflective spectroscopy.

2.5 Skin-carotenoid measurements

Skin reflective spectroscopy is a non-invasive method to determine carotenoid concentration, while blood tests and dermal biopsies are invasive. Blood tests are also not an accurate measure of long-term F/V intake due to the short half-lives of carotenoids, therefore, it is more suitable to use plasma carotenoids when assessing short-term F/V intake (Radtke et al.,

2020). Studies have shown that skin reflective spectroscopy has a strong correlation with plasma carotenoids, confirming that it is a reliable method to measure carotenoid concentration in the human body (Jahns et al., 2019; Jilcott Pitts et al., 2018). There are different instruments which can measure the SCS, for example, pressure-mediated reflection spectroscopy (RS), Resonance Raman spectroscopy (RRS) and spectrophotometers (Radtke et al., 2020). Pressure mediated RS measures SCS using a broad-band light source (Radtke et al., 2020). Pressure is added during the time of measurement which limits blood flow to the location where carotenoids are being assessed (Radtke et al., 2020). By limiting blood flow, the presence of oxygenated and deoxygenated haemoglobins is reduced which is important as these molecules can interfere with carotenoid absorption (Radtke et al., 2020). The density of skin-carotenoids is measured and laid upon a reflection-based absorption spectrum for reference (Radtke et al., 2020).

A study found that RRS and pressure mediated RS produced similar patterns when measuring SCS (Hwang et al., 2023). This study concluded that pressure mediated RS is faster, more convenient and simpler than RRS and could be used as an alternative method to measure SCS (Hwang et al., 2023).

In summary, studies show that pressure mediated RS is a faster and simpler measurement than RRS while producing similar results. Pressure mediated RS is a reliable, non-invasive method for measuring skin-carotenoid levels (Hwang et al., 2023). It also offers an alternative to invasive blood tests and biopsies (Jahns et al., 2019; Jilcott Pitts et al., 2018).

2.6 The Veggie Meter®

A type of pressure mediated RS is the VM®. The VM® measures the amount of orange light reflected from the fat pad of a fingertip (Rush & Bezzant, 2019). A single reading takes ten seconds, and an average is produced from three readings (Rush & Bezzant, 2019). The reading presents a score of between 0-800 nm, which indicates the SCS (Rush & Bezzant, 2019). Every 100 nm of the VM® score equals approximately one serving of fruit or vegetable (Di Noia & Gellermann, 2021). Adequate consumption of F/V reflects a higher VM® score (Rush & Bezzant, 2019). Currently, there are no ranges for what is considered a good and poor VM®

score for children. However, a study conducted in Japan came up with suggestions (Obana et al., 2022). A score greater than 507 nm was considered excellent, 396–506 nm was considered good, 311–395 nm was average, 240–310 nm was a shortage of vegetables in the diet, and less than 239 nm was considered a severe shortage of vegetables (Obana et al., 2022). The carotenoids measured by the VM[®] include α -carotene, β -carotene, β -cryptoxanthin, lycopene, lutein, and zeaxanthin (Liu et al., 2021). Studies show a variety of factors that can affect SCSs. Some studies have found that students from high-income schools had a low mean VM[®] score, while students from low-income schools had higher mean VM[®] scores (Martinelli et al., 2021). This may be attributed to the higher participation of low-income schools in the National School Lunch Program (NSLP) (Martinelli et al., 2021). NSLP provided children with low-cost or free meals that met specific nutrition guidelines (Martinelli et al., 2021). However, Nagao-Sato et al. (2021) found no correlation between household income and SCS.

SCS was hypothesised to be affected by ethnicity; May et al. (2020) found that white children had a higher SCS when compared to Latino, Black, and other racial groups, but (Martinelli et al., 2021; May et al., 2020) found no significant statistical difference. Rush et al. (2020) also found ethnicity to be an influencing factor. Pacific participants had the lowest SCS compared to other ethnicities, while Asian participants had the highest SCS (Rush et al., 2020). Martinelli et al. (2021) determined that there was no correlation between SCS and ethnicity, with a p-value of 0.326, indicating that the correlation was insignificant.

Burkholder et al. (2021) found that older children (5y) had a higher SCS than younger children (3-4y). Rush et al. (2020) also found a correlation between SCS and age, participants who were older than 40 had a higher SCS than the younger participants. In another study, preschool students had a higher mean SCS than middle school and high school students (May et al., 2020). Hasnin et al. (2023) and Martinelli et al. (2021) found no correlation between SCS and age.

Three studies found that boys had a higher SCS when compared to girls (Burkholder et al., 2021; May et al., 2020; Nagao-Sato et al., 2021). May et al. (2020) found that boys across preschool, middle school and high school had a higher mean SCS than the girls in the study.

However, Takeuchi et al. (2022) found that boys had lower median SCS than girls. Martinelli et al. (2021) found no correlation between gender and SCS.

Liu et al. (2021) and Rush et al. (2020) found that children with higher body weights/body mass index (BMI) had a lower SCSs, while four studies found no significant correlations between SCS and the weight/BMI of children (Hasnin et al., 2023; Jones et al., 2021; May et al., 2020; Nagao-Sato et al., 2021).

There were significant correlations between vegetable intake and SCS (Hasnin et al., 2024; Martinelli et al., 2021; Varghese et al., 2024). Less studies found a correlation between SCS and fruit intake, which can be attributed to the lower content of carotenoids in some fruits compared to vegetables (Takeuchi et al., 2022; Varghese et al., 2024). High school students had a significant correlation between SCSs and fruit intake (May et al., 2020). Hasnin et al. (2024) found no correlation between SCS and mean fruit consumption. Other authors have found a correlation between SCSs and total F/V intake (Hasnin et al., 2023; Hasnin et al., 2024).

Bayles et al. (2021), Burkholder et al. (2021), and Nagao-Sato et al. (2021) found that SCSs were lower in winter than in summer and autumn. However, Jones et al. (2021) found that SCSs increased from Autumn 2018 to Spring 2019 and were stable over the summer. No significant differences were found between Spring 2019 and Autumn 2019 (Jones et al., 2021). May et al. (2020) hypothesised that an increased intake of fizzy drinks resulted in a lower SCS.

Liu et al. (2021) found that children who had been exclusively breastfed for less than five months had a lower SCS than children who had been exclusively breastfed for more than five months.

To conclude, various factors affect carotenoid scores measured by the VM[®]. Martinelli et al. (2021) found that children's socioeconomic status affects scores, with higher scores seen in students from low-income schools due to participation in nutrition programs. The relationship between ethnicity and SCSs was inconsistent across studies (Martinelli et al., 2021; May et al., 2020; Rush et al., 2020). Age and gender correlations with SCSs are inconsistent, with

conflicting findings on whether older children or a specific gender have higher/lower SCSs (Burkholder et al., 2021; Hasnin et al., 2023; Martinelli et al., 2021; May et al., 2020; Nagao-Sato et al., 2021; Rush et al., 2020; Takeuchi et al., 2022). Some studies suggested that a higher BMI and body weight may be associated with lower SCSs (Liu et al., 2021; Rush et al., 2020), while some studies found no significant correlation (Hasnin et al., 2023; Jones et al., 2021; May et al., 2020; Nagao-Sato et al., 2021). High vegetable intake consistently correlated with higher SCSs, whereas fruit intake showed a weaker/no correlation (Hasnin et al., 2024; Martinelli et al., 2021; May et al., 2020; Varghese et al., 2024). Other factors found to influence SCSs included seasonal variations, fizzy drink consumption, and breastfeeding (Bayles et al., 2021; Burkholder et al., 2021; Jones et al., 2021; Liu et al., 2021; May et al., 2020; Nagao-Sato et al., 2021).

2.7 Validity and Reliability of a Modified 24-hour MPR in children

No studies have assessed the validity and reliability of the modified 24-hour MPRs in children against weighed food diaries with a focus on F/V intake. It is important that the validity and reliability of a measurement tool such as the 24-hour MPR is determined. By doing so, it is established if the estimated intake from the tool is accurate, consistent and replicable (Ahmed & Ishtiaq, 2021). Authors of several studies have looked at the general reliability and validity of 24-hour dietary recalls in children (Baxter et al., 2016; Foster & Bradley, 2018; St. George et al., 2016).

Foster and Bradley (2018) looked at the validity of 24-hour dietary recalls in children aged 4–12 years against energy expenditure measured by doubly labelled water and found that that multiple 24-hour dietary recalls were more accurate and valid to estimate food intake than a single 24-hour dietary recall. St. George et al. (2016) found that one 24-hour dietary recall produced an 11% accuracy, whereas three 24-hour dietary recalls produced a 62% accuracy. This study concluded that to achieve an 80% accuracy when measuring F/V intake, 21 to 32 24-hour dietary recalls were required for fruit intake and 21 to 25 24-hour dietary recalls are required for vegetable intake (St. George et al., 2016).

Burrows et al. (2010) concluded that three 24-hour dietary recalls were suitable for measuring energy intake in children between 4 and 11 years. Foster and Bradley (2018) also suggested conducting a 24-hour MPR over three days on children. The use of 24-hour MPRs validated against doubly labelled water has been shown to decrease underreporting by 2-8% in children when compared to a single 24-hour dietary recall (Foster & Bradley, 2018). Underreporting in 24-hour dietary recalls was seen to correlate with weight: as weight and BMI increased, underreporting was more likely to occur (Foster & Bradley, 2018). Foster and Bradley (2018) found that underreporting increased with age.

Some studies reported that children aged eight could accurately report their diet, but others found that only children ten and older could do so (Foster & Bradley, 2018). Two studies found no correlation between biological sex and accuracy of reporting intake during the 24-hour dietary recall (Börnhorst et al., 2014; Zhang et al., 2015). However, Baxter et al. (2016) reported that boys had greater inaccuracies in reporting than girls. Foster and Bradley (2018) found that girls underreported intake more than boys. Foods containing sugar and fat were underreported more than protein and starchy foods (Foster & Bradley, 2018). Protein was underreported by 2%, and energy intake was underreported by 14% (Foster & Bradley, 2018).

In summary, while no studies have specifically assessed the validity and reliability of 24-hour MPRs estimating F/V intake in children, general reliability and validity of 24-hour dietary recalls in children provides an insight. Studies conducted by Foster and Bradley (2018) and St. George et al. (2016) found that multiple 24-hour MPRs improve reliability and produce more accurate results. Burrows et al. (2020) reported that three 24-hour dietary recalls were a suitable number to conduct on children, but more than two starts to become a participant burden and increases time and research costs. 24-hour multiple pass recalls validated against doubly labelled water have been shown to reduce underreporting in children by 2-8% (Foster & Bradley, 2018). The likelihood of underreporting increased with age and can depend on weight and BMI (Foster & Bradley, 2018). The impact of biological sex on reporting accuracy remains inconclusive due to the conflicting results from studies (Baxter et al., 2016; Börnhorst et al., 2014; Foster & Bradley, 2018; Zhang et al., 2015). Foods which contained sugar and fat were underreported more than protein and starchy foods (Foster & Bradley, 2018).

2.8 Validation of weighed food diaries in children

Not many studies have examined the validity of food intake using weighed food diaries in children aged 9 to 13–years–old. No studies have looked at the validation of carotenoid levels using weighed food diaries in children. A study conducted in Australia on children between the ages of 8 and 11 looked at the validity of parents reporting the energy intake of their children versus children reporting their own intake using a FFQ compared to a weighed food diary (Burrows et al., 2013). Burrows et al. (2013) found that weighed food diaries produced a small bias with some underreporting of the child’s energy intake, this may have been because parents wanted their child’s intake to appear socially desirable. The FFQ conducted by the child produced an overreported energy intake (Burrows et al., 2013). The total energy intake of the weighed food diary only had a 5% difference in the daily kilocalories compared to the doubly labelled water method; therefore, it was deemed an accurate measure of total energy intake (Burrows et al., 2013). To the writer’s knowledge, no studies have compared a modified 24-hour MPR with weighed food diaries in children.

2.9 Statistical approaches for determination of validity and reliability

Multiple statistical approaches can be used to determine the validity and reliability of measurements in research. Reliability refers to consistency, while validity measures accuracy (Kimberlin & Winterstein, 2008). Reliability is defined as the consistency of a measurement under the same conditions (Kimberlin & Winterstein, 2008). A measurement is considered reliable when the same outcome is produced under consistent conditions (Kimberlin & Winterstein, 2008). Validity is defined as the accuracy of a measurement or the extent to which an instrument measures what it claims to measure relative to the actual measurement (Kimberlin & Winterstein, 2008). A common method used to measure validity is the Bland-Altman method. This method was not used in this study because of the creation of a bias when one measure is calibrated against a criterion even if there is no bias present (Hopkins, 2004). Due to this, the Bland-Altman method was not used to test validity.

Some examples of tests to measure reliability are typical error of estimate (TEE), intraclass correlation coefficient (ICC), change in mean, and Pearson correlation. TEE measures the variability present within repeated measurements. A smaller typical error indicates more

consistency (Hopkins, 2000). Some examples of tests to measure validity are linear regression, typical error of estimate derived from the regression, Pearson correlation, bias at x value and overall mean bias (Hopkins, 2000).

The Pearson correlation measures the similarity between two variables. It is performed by comparing the linear relationship between the two variables, which then produces a value between negative one and one (Berman, 2016). One indicates a linear relationship, zero indicates no linear relationship, and a negative one indicates a negative linear relationship (Berman, 2016).

Intraclass correlation coefficient measures the consistency within a class of data (Liljequist et al., 2019). ICC is measured between zero (poor reliability) and one (excellent reliability) (Liljequist et al., 2019).

Change in the mean refers to the difference in the mean values between two data sets (Hopkins, 2000). The standardised difference in mean is divided by the baseline standard deviation.

Tables 2.1 – 2.3 presents studies on the validity and reliability of dietary assessment tools with a focus on 24-hour MPRs, weighed food diaries and the Veggie Meter®. The tables highlight the methodologies, sample sizes and key findings from each study mentioned in the literature review in greater detail. The following research was identified from October 2023 – August 2024 by searching online databases, Google Scholar, Scopus, PubMed, MDPI, and Elsevier. Studies excluded were ones not conducted on children (18 y or older), and not in English. Key words used were “Dietary intake assessment”, “24-hour MPR”, “24-hour dietary recall”, “weighed food diary”, “fruit and vegetable”, “Veggie Meter®”, “validity”, “reliability”, “carotenoid”, and “children”.

Table 2.1 Overview of Veggie Meter® Literature

Country	Reference	Main Aim and Objectives	Study Population and Sampling	Methodology	Main Outcomes
US	(Martinelli et al., 2021)	If the VM® can be used on elementary school children for future studies.	154 9-11y students from five schools. School sample income was determined by the percentage of students eligible for free or reduced-price meals. Two schools were categorised as low-income, with 89% of eligibility, and three were categorised as high-income schools, with 4-13% eligibility.	Data collectors read survey questions about F/V consumption to students, for them to record answers. Following the survey, students had their non-dominant index finger cleaned and scanned three times on the VM®. An average score was generated.	Veggie Meter ® scores were unaffected by the child’s sex, age or race. Students from high-income schools had a lower mean VM® score (201 nm ± 80) than those from low-income schools (221 nm ± 59). There was a weak but statistically significant correlation between the total vegetable intake and VM® score (r=0.174, p=0.042), with higher scores linked to higher vegetable consumption. There were no correlations between other variables and VM®.
US	(Varghese et al., 2024)	Evaluated the relationship between SCS and F/V intake in diverse toddlers.	50 American toddlers, 12-36 months participated. Exclusion criteria: parents under 18 years, parents who did not make food decisions, not fluent in English, no phone, toddlers who could not walk, or above the ages of 12-36 months.	24 parents received an intervention in a playgroup setting, which included coaching on nutrition and activity. 26 parents were in the control group. They received the same weekly educational material without coaching. 10-12 weeks post-intervention, the SCS and dietary intake of the toddlers were recorded. Toddlers scanned their cleaned right index finger on the VM® using two methods: three scans over 90 seconds and a single scan over 10 seconds, followed by another scan. The weight, height and BMI of the children were measured. Parents completed a 31-item semi-quantitative FFQ for their toddlers.	There was a significant correlation between increased vegetable intake and higher SCS concentration (P<.006). Each 1-unit increase in vegetable servings led to a 16.62 nm increase in SCSs. Fruit intake did not significantly correlate with SCSs due to the lower carotenoid content in the fruits. β-carotene was the most influential carotenoid species for SCSs.
US	(Nagao-Sato et al., 2021)	Examined the relationship between SCS and food and vegetable intake in low-income Latino adolescents.	195 low-income Latino children 10-14y were recruited from a community-based father-child intervention program.	Participants completed three 24-hour dietary recalls, one in person and two over the phone, using the National Cancer Institute method to estimate the amounts of food eaten. An average SCS was	A significant relationship between F/V intake and increased SCS was found with a p-value of <0.01. SCSs were higher in Fall (September-October) and lower in Winter (January-March). The employment status of fathers did not influence

				collected using the VM®. BMI, height and weight were also measured. Fathers completed a general questionnaire about themselves and their household.	SCS. F/V accessibility and availability influenced SCSs. F/V intake was lower than the recommended intake. Boys had a higher SCS, however females had a higher mean carotenoid and F/V intake. There was no significant correlation between weight and SCS.
US	(Burkholder et al., 2021)	Explored how time, age and sex affected SCSs in children 3-5y.	112 children aged 3-5 y were recruited. Inclusion criteria: aged 3-5 y, enrolled at Head Start, consent from a parent or guardian, no disabilities and spoke English.	Height, weight and SCSs using the VM® were measured three times over the school year (October, December, and February) with 2-month breaks between each measurement. Parents were asked to complete a survey about their children.	The average SCSs for time points one to three were 266 nm, 273 nm and 229 nm, respectively. SCSs increased with age, 241 nm in 3-year-olds, 267 nm in 4-year-olds and 339 in 5-year-olds. A positive relationship between SCSs and F/V intake was observed. SCS decreased between December and February, from 273 nm to 229 nm. This is likely due to the decrease in the availability of F/V during winter, which is reflected in the low SCS in February. The VM® scores represent a carotenoid intake over 4-8 weeks. These SCSs would have been over winter, indicating lower intake at home. Boys had a higher SCS and F/V intake than girls.
US	(Liu et al., 2021)	Analysed the relationship between breastfeeding, SCS and weight in school-aged children.	81 children aged 7-12 y were recruited from East-Central Illinois. Inclusion criteria: being between 7-12 y and not having an autism spectrum diagnosis.	The VM® was used to measure the participants SCSs. Three single scores were taken each time over nine visits. Eye vision was measured using a MPOD over three visits. Weight, height and BMI were measured. Each participant also had their adiposity measured using DXA. Participants and their parents completed a seven-day food diary, which was then analysed using the Nutrition Data Systems Research with a focus on total energy and carotenoids. Parents also completed a questionnaire	The mean SCS was 304 nm. BMI, percentage of fat, and visceral adiposity tissue had an inverse correlation with SCS. No correlation was found between MPOD and SCS. A positive correlation was observed between SCSs and dietary carotenoid intake. Lower SCS was observed in participants who were exclusively breastfed for <5 months (279 nm) compared to participants who were exclusively breastfed for ≥ 5months (329 nm, P=0.03)
US	(Bayles et al., 2021)	Analysed the effect of food-based science, technology, engineering,	113 children from Head Start preschools in North Carolina participated. Inclusion criteria: aged	11 classrooms took part in six interventions and five comparison classrooms. The intervention group went	No changes in vegetable liking was observed in either group. SCSs for both groups increased from baseline to midpoint; however they

		arts and maths (STEAM) activities on F/V intake and preferences of foods on preschoolers.	3–5 y, enrolled in a Head Start centre, and consent from the parent/guardian. Exclusion criteria: having a disability and/or not speaking English.	through four months of food-based STEAM activities, which focused on vegetable exposure. Parents completed a survey on their child’s vegetable preferences at baseline, midpoint and post-study. SCS was measured using the VM® at three-time points, with three measurements averaged each time.	decreased post-study, which may reflect a home diet as participants were on winter break. The intervention group had a significantly smaller decline from baseline to post-study ($p=0.02$). The intervention group’s post-study SCS was significantly higher ($267.8 \text{ nm} \pm 11.26$) than the comparison group’s ($229.6 \text{ nm} \pm 10.32$).
JP	(Takeuchi et al., 2022)	Assessed the relationship between SCSs and F/V intake in Japanese children.	328 10y from three primary schools in Japan participated. Exclusion criteria: not being able to measure SCSs.	Parents completed a questionnaire about their children. SCSs were measured using the VM®.	The median SCS was 335 nm. Boys had a lower median SCS (325 nm) than girls (344 nm). A positive correlation was found between SCSs and fruits, vegetables, yoghurt, and exercise. A negative correlation was found between SCSs and meat, fish, ready-to-eat foods, fried foods and passive smoking.
NZ	(Rush et al., 2020)	Evaluated the determinants of SCS in women and men of different ethnic backgrounds, ages, and body sizes.	571 participants from Auckland and Hamilton, New Zealand participated. 324 women and 247 men. Participants were 16 or older.	Participants completed a FFQ and then measured their SCS using the VM® by placing their cleaned right index finger and taking three consecutive measurements.	Participants over 40 y had a higher SCS than the younger participants. Pacific participants had the lowest SCS while Asian participants had the highest. Higher BMI was associated with a lower SCS by 5.4 units.
US	(May et al., 2020)	Analysed the relationship between SCS and F/V intake in a preschool and school setting.	112 preschool students, 94 middle school students and 58 high school students participated.	Preschool students completed a validated dietary intake pictorial survey on an iPad, rating food pictures on a five-point scale from “super yucky” to “super yummy.” Middle school students completed a validated school physical activity and nutrition (SPAN) questionnaire about their F/V consumption the previous day, as well as physical activity and fizzy drink consumption. High school students used the National Cancer Institute Fruit and Vegetable Screener to assess their F/V intake over the last month. SCS was measured by placing the index finger on the VM®. Preschoolers had a single scan,	No significant correlation was found between SCS and the pictorial survey or the SPAN questionnaire. A significant correlation between fizzy drink intake and SCS in middle school students was found. A significant correlation was found between SCSs, and daily fruit intake in high schoolers. No correlation between SCS and F/V intake was found in preschool and middle school children. Preschool students had a higher mean SCS. Boys across all age groups had a higher mean SCS. No significant correlation was found between weight, ethnicity, and SCSs.

				while middle school and high school students had three scans, averaged.	
US	(Jones et al., 2021)	Compared F/V consumption in low-income school settings to SCSs.	35 students in grades 3 to 5 from schools with >50% of students who qualified for free or reduced-price meals participated.	Participants received a consent packet with a demographic questionnaire. The study was conducted in Fall 2018, Spring 2019, and Fall 2019. Participant's weight, height, BMI were measured and their SCS was measured using the VM®. In Fall 2018 and Spring 2019, VM® measurements were taken from the dominant index finger, and in Fall 2019, the non-dominant ring finger.	VM® scores increased from Fall 2018 to Spring 2019 but were stable over the summer. No significant difference was found between Spring 2019 and Fall 2019, and no significant association was found between BMI and VM® scores.
US	(Hasnin et al., 2024)	Evaluated the evidence that validates criterion-related RS-based SCSs against F/V consumption in preschool children.	136 3-5 y participated. Inclusion criteria: over the age of two, no preschool siblings, lunch provided and full-time enrolment in school.	Cross-sectional data was collected using an online survey. Data was collected over two non-consecutive days. On the first day, height, weight, and SCSs were measured using the VM®. A single scan was measured using the sanitised left ring finger of each child. The research assistant observed lunchtime and recorded the quantity served and eaten by children. Parents completed an online FFQ about their child's F/V intake.	Observation data and parent-reported F/V consumption showed a small but significant correlation with SCSs. Skin carotenoid score had a relationship with mean F/V intake and mean vegetable intake but not with mean fruit intake. Mean F/V intake had a significant correlation with the FFQ scores. This study concluded that the VM® was a potentially valid and feasible tool.
US	(Hasnin et al., 2023)	Assessed the validity of the VM® and determine if it can be used to analyse F/V consumption in non-Hispanic White preschool children.	66 non-Hispanic White children 3-5 y who attended family childcare home settings in Nebraska were recruited.	Children's weight, height, and BMI were measured, as well as their SCS using the VM®. Parents completed an FFQ about their child's F/V intake.	A significant association was found between SCS and F/V consumption, $r=0.26$ ($p=0.04$). No correlation was found between SCS, weight, BMI, age, or biological sex. A small effect size was found for the validity of the VM® suggesting good validity. SCS was concluded to be a suitable substitute for parent-reported F/V consumption in preschool children.

Table 2.2 Overview of Modified 24-Hour Dietary Recall Literature

Country	Reference	Main Aim and Objectives	Study Population and Sampling	Methodology	Main Outcomes
GB	(Foster & Bradley, 2018)	Analysed studies which used 24-hour dietary recalls to determine what considerations need to be taken when using them on children.	N/A	N/A	Repeated 24-hour dietary recalls are more accurate than a single 24-hour recall. 24-hour MPRs reduce underreporting rates by 2-4% in boys and 4-8% in girls. Underreporting increased with BMI and was more common for sugary and fatty foods. Parents who wanted to appear healthier may have altered their child's regular diet. Some studies reported that eight-year-old children could accurately recall their diet, however, some reported that the accuracy improves at the age of ten. Underreporting increased with age, particularly in girls and overweight or obese children. Three-day 24-hour MPR is recommended for children.
US	(Baxter et al., 2016)	Analysed food consumed by children and determined reporting accuracy.	455 children from ten schools over three years (2011-2012 to 2013-2014) were recruited.	Participants were observed for two consecutive days at school during breakfast and lunch by researchers who recorded the items and amounts eaten. On the same day, the participants completed a 24-hour recall. Two retention intervals were used: a short interval (afternoon interview covering the previous 24 hours) and a long interval (morning interview covering the previous day).	There were 667 intrusions (food recalled but not observed), 1607 omissions (food observed but not recalled), 376 overreported, 608 underreported and 970 matches (observed and reported amounts matched). Mean kilocalorie inaccuracy was highest in omissions and lowest in overreported. Inaccuracies were more significant in boys, at breakfast time, and higher with a long retention interval.
US	(St. George et al., 2016)	Analysed the reliability of 24-hour dietary recalls measuring energy, fat, F/V intake and how reliability varies with the number of recalls.	456 10–17 y African Americans were recruited for three studies.	Three studies were carried out: a cross-sectional health study (study 1), a family-based health promotion intervention (study 2) and a weight loss efficacy trial (study 3). Participants in all studies completed a 24-hour dietary recall.	Three 24-hour dietary recalls on children produced low reliability. The accuracy of one 24-hour dietary recall was 11%, while three recalls increased the accuracy to 62%. To achieve 80% reliability, eight recalls for energy

				Studies one and two used a modified automated self-administered 24-hour protocol, while study three used a dietitian/nutritionist for the recall.	intake, 13 for fat intake, 21-32 for fruit, and 21-25 for vegetable intake are needed.
US	(Weber et al., 2004)	Assessed the validity of a modified 24-hour dietary recall in American Indian children aged 8-10 y.	Eight ten-year-old American Indian children took part.	Children were trained to record their diet and estimate portions. They received measurement tools and recording material and began recording after their school lunch, continuing until after the next day's breakfast. During school meals, observers measured and recorded leftover food. After breakfast the next day, children were interviewed using the 24-hour MPR method with food models and utensils as prompts.	No significant difference was found between observed and recalled total energy intake for school meals. The total energy intake was overestimated by 13% for both meals, 23% for breakfast, and 7% for lunch. Significant differences were found between the observed and recalled total carbohydrates and protein in both school meals. No significant difference was found in the percentage of energy from fat, carbohydrates and protein. The observed foods were categorised into 15 groups, of which children accurately recalled nine food groups (83%), with "added foods" (condiments, spreads) being the least accurate. A total of 702 foods were observed, of which 527 (75%) were correctly recalled. 581 out of 702 foods were found in both the observed and recalled foods; 73 were missed on recalls, and 48 were recalled without observation. 57% of foods were correctly recalled within 10% of the observed amounts. In 14% of recalls, observed amounts were overestimated by 11-99%. Overestimation of observed amounts by >100% was seen in 16% of recalls. 13% of foods were underestimated.

Table 2.3 Overview of Weighed Food Diary Literature

Country	Reference	Main Aim and Objectives	Study Population and Sampling	Methodology	Main Outcomes
AU	(Burrows et al., 2013)	Compared the accuracy of a FFQ with that of a weighed food diary in reporting children's energy intake.	Nine 8-11 y took part. Inclusion criteria: having two caregivers, BMI between 18.35 to 20.74, no medical conditions, and not on medications affecting weight.	This study took place over ten days. Daily urine samples were collected before and after an oral dose of doubly labelled water to measure energy expenditure. Participants weight and height were measured on days one and ten after an overnight fast. Dietary intake was measured using the FFQ, completed by the child and two caregivers, and a four-day weighed food diary (including two weekdays and at least one weekend) by the parents.	Weighed food diaries produced a small bias, with some underreporting of the child's energy intake. The FFQ completed by the child had some overreporting bias, while the parent-completed FFQ had greater over-reporting bias, especially by mothers. The child-completed FFQ's energy intake was closest to the doubly labelled water measurement, while the mothers was the least accurate. The four-day weighed food diary had only a 5% difference from the doubly labelled water method. The weighed food diaries were more likely to produce an underreported energy intake, while the child-completed FFQ was more likely to produce an overreported energy intake.

Chapter 3

3.0 Research Manuscript

3.1 Abstract

Background

Adequate intake of fruits and vegetables (F/V) is essential for children's growth and development, yet many New Zealand children may not consume enough. Sufficient F/V intake reduces the risk of non-communicable diseases (NCDs) and certain cancers. However, no comprehensive nutrition survey on New Zealand children has been conducted in over 20 years. Additionally, the validity and reliability of a modified 24-hour multiple pass recall (MPR) for assessing dietary intake in this population have not been examined. This study aimed to evaluate the validity and reliability of a modified 24-hour MPR compared to weighed food diaries for measuring F/V intake. Additionally, spectrophotometer called the Veggie Meter (VM®) was used to explore the relationship between F/V intake and skin carotenoid levels, while I also determined the intra- and inter-day reliability of the VM® .

Aims

To establish the feasibility, validity and reliability of the modified 24-hour MPR for the evaluation of carotenoid and fruit and vegetable intake against weighed food diaries in 9 to 13-year-old school children living in Auckland. To estimate the reliability of the VM® as a tool to measure chronic skin carotenoid levels.

Methods

Thirty two children ($n= 20$ boys; $n= 12$ girls) aged 9–13 years living in Auckland, New Zealand took part in this study. Intake of F/V were measured using a modified 24-hour MPR completed by the child, a weighed food diary completed by the parent and skin-carotenoid score (SCS) using the VM® on a randomised weekday and weekend day. The validity of the modified 24-hour MPR, relative to the weighted diary as the criterion measure, was tested for by using measures such as log-transformed Pearson correlation, bias at X value derived from regression analysis, and overall mean change in mean. Reliability of the modified 24-hour MPR F/V serving quantities were determined from raw arithmetic difference vs the

weighed food diary, while reliability of the 24-hour MPR carotenoid intake ($\mu\text{g}/\text{d}$) was expressed as a ratio of the by-day modified 24-hour MPR/weighed food diary. Inter-day reliability of the modified 24-hour MPR and the VM[®] SCS reliability were tested for by using measures such as the log-transformed change in mean, typical error as a coefficient variation (CV), Pearson correlation, and intraclass correlation coefficient (ICC).

Results

Participants did not meet the recommended servings of fruits or vegetables per day for the modified 24-hour MPR ($\mu= 1.31$ serves of fruit; $\mu= 2.00$ serves of vegetables) and weighed food diaries ($\mu= 1.26$ serves of fruit; $\mu= 1.87$ serves of vegetables). Boys had an overall higher fruit, vegetable, total F/V, and carotenoid intake. The average VM[®] mean score was 287 nm, and girls had a higher score ($\mu= 286 \text{ nm} \pm 107 \text{ nm}$ for girls and $\mu= 280 \text{ nm} \pm 66 \text{ nm}$ for boys). The validity tests for the modified 24-hour MPR found the modified 24-hour MPR to be valid however there was bias. The bias at X value for moderate to very large (0.63–3.53 serves). This test result indicated that the estimated intake of the modified 24-hour MPR would need to be adjusted to offset the bias. Testing the modified 24-hour MPR for reliability using change in mean was found to be unreliable to estimate carotenoid: 8.2% (90% CI -23, 53), fruit: -2.19 (90% CI, -3.4, -1.0), vegetable: 0.19 (90% CI -0.8, 1.2) and total fruit and vegetable: -1.0 (90% CI -2.2, 0.1) intake. The typical error as a percentage CV for estimated carotenoid intake was: 126% (90% CI 97, 180.6). Typical error for estimated fruit intake was 2.7 (90% CI 2.3, 3.5), for vegetable intake: 2.4 (90% CI 2.0, 3.0), and for total F/V intake: 2.7 (90% CI 2.2, 3.4). These values ranged from small to very large), indicating unreliability. The VM[®] was found to be a reliable instrument with low percentages of change in mean and low percentages of typical error as a CV.

Conclusion

The modified 24-hour MPR was an unreliable but valid tool to estimate F/V and carotenoid intake in New Zealand children. However, the VM[®] was found to be a reliable instrument to determine skin carotenoid concentration and therefore metric to estimate physiological availability and dietary intake of these phytochemicals.

3.2 Introduction

The last national nutrition survey on children in New Zealand was over 20 years ago (Parnell et al., 2003). An up-to-date survey is required as the last nutrition survey is outdated and eating habits have likely changed since 2002. Since the early 2000s, New Zealand's ethnic diversity has grown considerably. In 2001, there were approximately 500,000 people who identified as Māori, 200,000 people who identified as Pacific, 200,000 people who identified as Asian and 24,000 other ethnic groups (Stats New Zealand, 2024b). The 2023 New Zealand census showed that New Zealand has approximately 800,000 people who identified as Māori, 800,000 people who identified as Asian, 400,000 people who identified as Pacific and 92,000 people who identified as MELAA (Middle Eastern, Latin American and African) people (Stats New Zealand, 2024a). As the data shows, the number and relative proportion of people in each ethnic group is increasing, affecting the type of foods available and eaten in New Zealand. Not only are the types and variety of foods available different now than in 2002, but the cost of food relative to income has also changed, impacting what is eaten by this generation of children. An up-to-date survey would reveal what current food trends children follow, what their diets look like, what their diets lack and what is adequate. The national nutrition survey on children also used a 24-hour MPR (Parnell et al., 2003).

We wanted to determine if modifications made to the 24-hour MPR for this current study would improve performance of the tool as measured by reliability and validity metrics. The first modification was the involvement of parents which was not done on children between the ages of 9-14 years-old in the national nutrition survey on children (Parnell et al., 2003). The involvement of parents allows to fill the gaps of brand names and recipes which children would have not necessarily known. Other modifications were the use of the Lilacs NZ food portion sizes — photographic atlas and measuring tools such as measuring cups and spoons to aid with portion estimation (Nelson et al., 1997).

This study aimed to determine if a modified 24-hour MPR can be used as a reliable, and feasible method to assess F/V intake and to evaluate carotenoid levels in future surveys of New Zealand children. Fruit and vegetables are an important aspect of a child's diet. Fruit and vegetables intake are associated with improved growth in children and has been shown to

lower the risk of heart disease, diabetes, and cancer (Rush et al., 2019; WHO, 2023). Adequate F/V intake has also been shown to help with weight management and prevent obesity (Rush et al., 2019; WHO, 2023). By assessing the feasibility, validity, and reliability of the modified 24-hour MPR, a more efficient and low-cost method to estimate food intake can be determined. Methods such as weighed food diaries can be time consuming and a burden to participants. Methods such as the doubly labelled water require time to train researchers and would be costly. The use of the 24-hour MPR to estimate food intake can save time, money and not be a burden to participants.

To the best of the writer's knowledge, no studies have determined the validity and reliability of estimating F/V intake using the modified 24-hour MPR when compared to weighed food diaries. Therefore, a validated dietary assessment is required in this population. There are multiple dietary assessments such as FFQs, 24-hour dietary recalls, and weighed food diaries. This study aimed to assess the reliability, feasibility and validity of a modified 24-hour MPR compared to a weighed food diary.

New Zealand's recommendation of daily vegetable intake for 9 to 13-year-old children is between 5–5.5 servings a day and at least two servings of fruit a day (Ministry of Health, 2023a). However, most children in New Zealand do not meet this requirement. The 2022/23 New Zealand health surveys revealed that less than 5% of children met the F/V intake recommendation (Ministry of Health, 2023b). Specifically, only 5.4% of children met the vegetable recommendation, while 70.9% met the fruit intake recommendation (Ministry of Health, 2023b). A direct measure of chronic carotenoid intake is available in the form of the VM[®]. The VM[®] is a non-invasive spectrometer that measures carotenoid levels in the fat pad of a fingertip, which has been previously shown to highly correlate with servings of F/V in the diet (Hasnin et al., 2023; Hasnin et al., 2024; Martinelli et al., 2021; May et al., 2020; Varghese et al., 2024). A higher VM[®] skin-carotenoid score (SCS) indicates a higher consumption of F/V (Rush & Bezzant, 2019).

Results from this study will be used to determine the feasibility of whether the modified 24-hour MPR can be used to collect food intake data from children in New Zealand, which can

inform future research. In addition, the results will provide a pilot-level update of the average and variability in F/V intake in a sample of New Zealand school children in 2024. This will also aid in future sample size estimation for future studies.

3.3 Methodology

3.3.1 Study design

This design was a randomised repeated-measure observational study comprising of repeats of two dietary assessments per child: a modified 24-hour MPR completed by the child and a weighed food diary completed by the child's parent or caregiver under the instructions and supervision of the researchers. Each child-caregiver pair were randomly assigned to the assessment of either a weekday/school day first, followed by a weekend day or vice versa. The weighed food diary provided the only practical way to qualitatively and quantitatively assay free-living food intake of the children and therefore was used as the criterion reference method to establish the validity and reliability of the modified 24-hour MPR. The dietary assessments were collected to determine the reliability and validity of the modified 24-hour MPR against weighed food diaries in New Zealand children aged 9-10 years. Participating children received a \$75 supermarket voucher and participating schools received a \$200 supermarket voucher on completion. A summary of the study outcomes was provided to the participants and parents by way of recorded narrated internet link.

3.3.1.1 Ethical considerations

This study involved the participation of children therefore, it was especially important to consider their age. Children gave verbal consent, and their parents/caregivers gave written consent, as children were under 16 years of age. Researchers underwent Police vetting. All procedures were reviewed and approved by the Massey University Human Ethics Committee, Ohu Matatika 1, Application OMI 23/46.

3.3.2 Participants and Recruitment

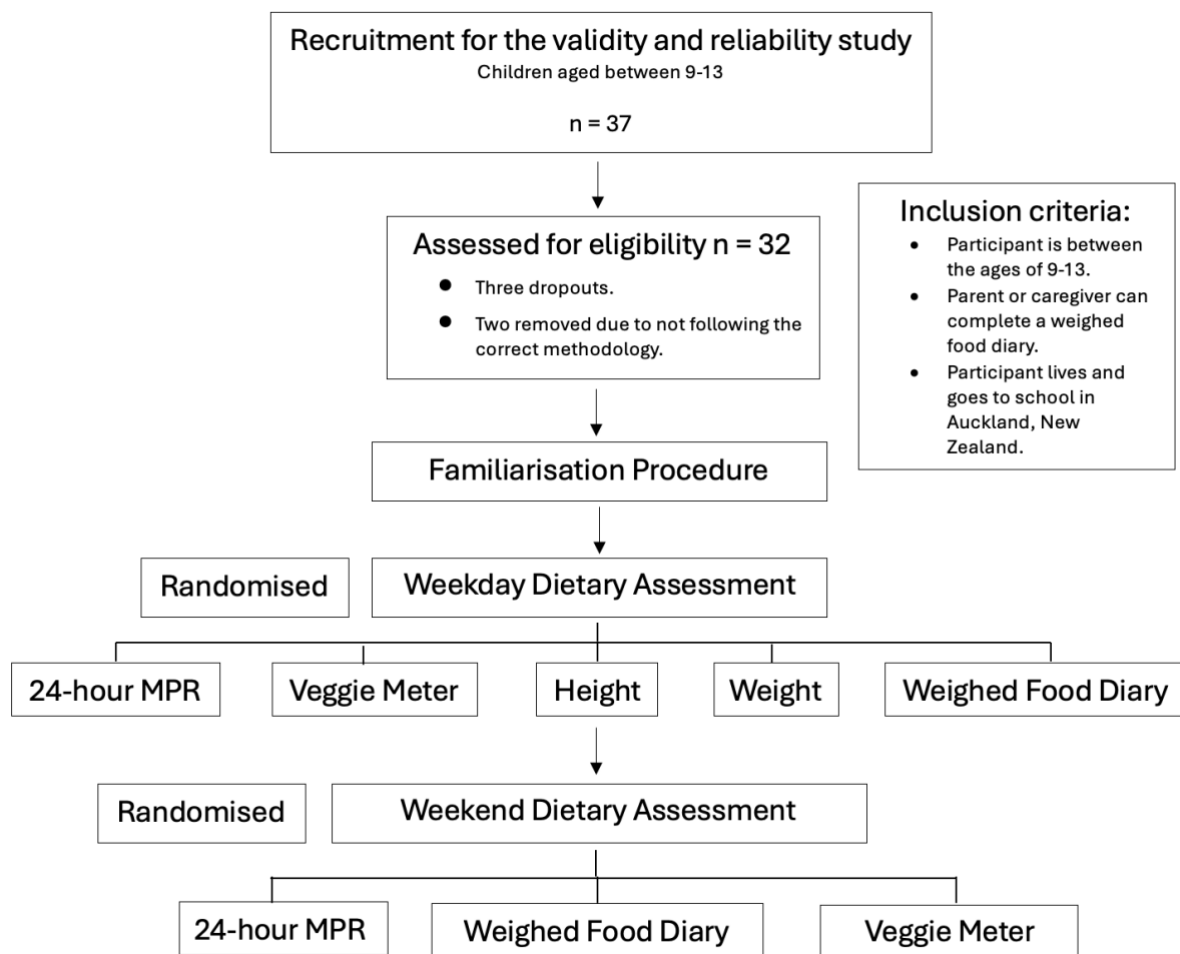


Figure 3.1. Requirement of the feasibility study (inclusion).

Thirty seven participants who lived in Auckland, New Zealand, aged 9–13 years, were recruited (Figure 3.1). This age was decided as we believed nine was the youngest age children, on average, could accurately complete a modified 24-hour MPR without intensive adult assistance (Burrows et al., 2010). A sample size of at least 31 participants for this study was determined based on the ICC. A study conducted by Nightingale et al. (2016) found that the average ICC for a weighed and modified 24-hour MPR was 0.98 for energy, 0.97 for protein and 0.94 for iron. Assuming an ICC of 0.9 for energy intake with a 95% confidence interval and an expected dropout of 10%, 25 children would be required (Borg et al., 2022). For this study, a sample size of 31 participants was determined while expecting a 20% dropout. Participants were excluded from this study if they were under the age of nine or

over 13 (Figure 3.1). Participants were also excluded if they did not live and attend school in Auckland, New Zealand (Figure 3.1).

3.3.3 Procedure, Data Collection and Handling

Schools with higher equity index numbers were emailed about participation in our study; however, these schools declined participation. We then emailed and/or phone called any school within a 10km distance from Massey University, Albany. Volunteering schools around Auckland distributed study invitations via a letter to parents/caregivers of children aged 9–13 years. Parents were also recruited through word of mouth, posters displayed in community libraries, centres, supermarkets and Facebook community groups (Appendix A, Supplementary Table 1). Parents and children who were recruited through volunteering schools received a briefing session on the study where questions could be answered. All the parents/caregivers received a study information sheet and a consent form, which was required to be returned to the researcher (Appendix A, Supplementary Tables 2 and 3). The consenting child-parent/caregiver pair took part in a familiarisation meeting.

Over a one-to-three-week period, each parent completed a randomised weekday and weekend weighed food diary for their child (Figure 3.1). The following day after the weighed food diary was completed, the child completed a weekday and weekend (completed on Monday or Sunday) modified 24-hour MPR (Figure 3.1). After each modified 24-hour MPR was collected, the child completed a VM[®] reading, which was completed three times to calculate an average (Figure 3.1).

3.3.4 Familiarisation Procedures

Each child-parent/caregiver pair went through a familiarisation procedure before carrying out the weighed food diaries and the modified 24-hour MPR (Figure 3.1). This procedure was conducted by either the writer or research assistant, and it took ~30 minutes. It consisted of introducing and familiarising the child with the modified 24-hour MPR by practising the method on them, training the parents on completing a weighed food diary, and informing them on what type of detail is required. Parents were also asked to fill out a VM[®] questionnaire regarding their child's intake of F/V, supplements and other foods high in

vitamin A (Appendix A, Supplementary Table 4). At the end of the familiarisation procedure, child-parent/caregiver pairs were offered the opportunity to ask questions and then provided with the required equipment.

3.3.5 Modified 24-hour MPR

The modified 24-hour MPR was adopted and adapted from the National Children's Nutrition Survey (Parnell et al., 2003). The modifications implemented to the 24-hour MPR included a familiarisation process prior to the interviews, parental support in the third phase of the recall, the use of the Lilacs NZ food portion sizes — photographic atlas (Nelson et al., 1997) and measuring equipment to assist with portion estimations and conducting the recall without computer assistance. Researchers interviewed participants the following day after the completion of their weighed food diaries. One weekday modified 24-hour MPR and one weekend modified 24-hour MPR were conducted. In the first pass (Appendix A, Supplementary Table 5), the researcher interviewed the child and recorded an uninterrupted quick list of their food and drink intake. In the second pass (Appendix A, Supplementary Table 6), a detailed list of the child's food and drink intake was recorded; this included specifics such as time, place, brand, and amount, which was aided using tools such as the Lilacs NZ food portion sizes — photographic atlas (Nelson et al., 1997) and measuring equipment. The third pass consisted of reviewing the food and drink intake with the child and parent/caregiver to fill in any gaps by probing and retrieving any recipes or brands that were provided. The information from the modified 24-hour MPR was entered into FoodWorks V.2.0 (Xyris Pty Ltd, 2024), which provided the nutrient intake of each child.

3.3.6 Weighed Food Diary

The researchers provided the parents or caregivers with written instructions and in-person tutorials. They were also provided with scales, measuring spoons and cups, and a printed copy of the recording booklet (Appendix A, Supplementary Table 7). With the provided equipment, the parents were required to record how much their child ate and drank in the booklet and take photos of all the food and drinks (including uneaten food). Information on food and drinks purchased at school was obtained by asking the children to explain what they ate or

retain packaging for their parents to record. The weighed food diary results were collected following the completion of both modified 24-hour MPRs to minimise carryover bias.

3.3.7 Veggie Meter®

The Veggie Meter® (VM®) is a non-invasive tool used to assess dietary carotenoids through the skin (Radtke et al., 2021). Carotenoids are a biomarker for F/V consumption due to the high levels in these foods and their inability to be synthesised by the body. Before its use, the VM® was calibrated using dark and light reference materials; repeat calibrations occurred every hour. Participants were required to wash and dry their hands thoroughly. Their right index finger was then placed facing down on the bulb of the VM®. The VM® scanned the finger pad due to the lower melanin levels which prevented results from being affected by high melanin levels. Three scans were taken, and this produced scans between 0-800 nm wavelength range with an allowance of less than 10% variability between each score. An average was then calculated using the three scores. The results from the VM® was used to assess the accuracy of the modified 24-hour MPR and weighed food diaries for assessing dietary F/V and carotenoid intake.

3.3.8 Training Research Assistants

One research assistant was recruited to conduct the modified 24-hour MPR on 22 participants and analyse this data. The writer completed 12 participants and analysed their data. Both researchers were trained in conducting the modified 24-hour MPR through role-playing. Feedback was provided during the training. Both researchers were also guided through the Lilacs NZ food portion sizes — photographic atlas (Nelson et al., 1997).

3.3.9 Dietary Data

The modified 24-hour MPRs were conducted at either the participant's home, school in a classroom, or at Massey University. Each session consisted of conducting a modified 24-hour MPR and a VM® reading (Figure 3.1). The first 24-MPR session also included taking the weight and height of the participant (Figure 3.1). Each session took approximately 20-30 minutes. The Lilacs NZ food portion sizes — photographic atlas (Nelson et al., 1997) and measuring

spoons and cups were used to aid with portion estimation. SCS was measured at both sessions; the research assistant took three consecutive measurements each session.

3.3.10 Data Handling

The modified 24-hour MPR and weighed food diaries were analysed by two different researchers to prevent carryover bias. The New Zealand food and nutrition guidelines for healthy children and young people (aged 2-18 years) was used as a guide as to what is determined as a serving of F/V (Mackie, 2015). Examples of one serving size of F/V included 130 g of apple, banana or orange, 135 g of canned fruit, 50-80 g of cooked vegetables, 135 g of potato or kumara and 60 g salad (Mackie, 2015). The total carotenoid amount from the modified 24-hour MPR and weighed food diaries was calculated from the sum of lycopene, lutein, zeaxanthin, β -carotene, α -carotene, and β -cryptoxanthin from FoodWorks V.2.0 (Xyris Pty Ltd, 2024).

3.3.11 Dietary Analysis

Nutrient and food group analysis of the modified 24-hour MPR and weighed food diaries were uploaded to FoodWorks V.2.0 (Xyris Pty Ltd, 2024), a nutritional analysis program (Xyris Pty Ltd, 2021). Brands, takeaways and other foods that were unavailable within the FoodWorks V.2.0 database (Xyris Pty Ltd, 2024) were manually entered using nutrition panels provided on supermarket websites and takeaway websites. Data input from the modified 24-hour MPR was completed by a researcher and research assistant. The weighed food diaries were completed by another research assistant to minimise bias.

3.3.12 Statistical Analysis

The statistical analysis of FoodWorks V.2.0 (Xyris Pty Ltd, 2024) and the VM[®] data was performed in Excel using spreadsheets to estimate validity and reliability (Hopkins, 2017).

The validity of the modified 24-hour MPR to estimate nutrient intake was compared to weighed food diaries, which were used as a criterion measure. Measurements used to determine validity for carotenoid intake were, log-transformed Pearson correlation, log-transformed standardised bias at X value derived from regression analysis, and overall mean bias. For F/V serves, raw data was used instead of log-transformed data due to zero values.

The reliability of the modified 24-hour MPR fruit, vegetable and total F/V serving intake was expressed as the by-day (weekday and weekend days) difference between the modified 24-hour MPR and weighed food diary to create a value of the by-day intake; this approach was taken over log-transformation because of values of zero for some samples between the two forms of diaries and zero cannot be log-transformed. The reliability of the modified 24-hour MPR carotenoid intake ($\mu\text{g}/\text{day}$) was expressed as the by-day $100 \times$ natural log 24-hour MPR/weighed food diary ratio. The values for the VM[®] SCS were log-transformed. Inter-day reliability of the modified 24-hour MPR and the VM[®] SCS reliability were determined from the log-transformed percentage change in the mean, mean log-transformed typical error as a CV (%), mean log-transformed Pearson correlation, and mean log-transformed ICC.

The typical error as a CV (%) is the typical error presented as the mean score of the estimated intake (Hopkins, 2017). Typical error of estimate measured the variability present within repeated measurements. A smaller typical error indicated more consistency, while a larger typical error indicated greater inconsistencies (Hopkins, 2000). The standardised typical error of estimate was calculated by taking the expected single-estimate (within test/ modified 24-hour MPR) divided by the sample variation (standard deviation), this displays the magnitude of the error by how many standard deviations the single estimate of typical error is.

The Pearson correlation measured the similarity between two variables. It was performed by comparing the linear relationship between the two variables, which then produced a value between negative one and one (Berman, 2016). One indicated a linear relationship, zero indicated no linear relationship, and a negative one indicated a negative linear relationship (Berman, 2016).

Standardised bias at X value evaluated the difference between the modified 24-hour MPR and weighed food diaries. It was calculated by dividing the mean bias of the modified 24-hour MPR by the standard deviation of the weighed food diary. Standardised overall mean bias is the average difference between the modified 24-hour MPR and weighed food diaries. Both measures indicated overestimation when the bias was positive while a negative bias

suggested underestimation. The values were interpreted using the modified Cohen scale. A smaller value indicated good validity whereas a larger value indicated poor validity.

Intraclass correlation coefficient measured the consistency within a class of data (Liljequist et al., 2019). The threshold for ICC were as follows: >0.1 = small, 0.3 = moderate, >0.5 = large, >0.7 = very large, >0.9 = extremely large (Hopkins, 2007).

Percentage change in the mean referred to the difference in the mean values between two data sets (Hopkins, 2000). The standardised difference in mean was divided by the baseline standard deviation. A larger percentage indicated a greater change in mean therefore poor reliability.

The modified Cohen scale was used to interpret the magnitude: raw and log-transformed TEE, and raw and log-transformed bias at X value and overall bias for validity. The modified Cohen scale values for TEE were as follows: <0.1 = trivial, 0.1–0.3 = small, 0.3–0.6 = moderate, 0.6–1.0 = large, 1.0–2.0 = very large, >2.0 = extremely large The modified Cohen scale values for bias at X value and overall bias were as follows: <0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, 2.0–4.0 = very large, >4.0 = extremely large.

The thresholds for the measurement of standardised raw change in mean and standardised raw typical error for reliability were as follows: 0.2 = small, 0.6 = moderate, 1.2 = large, 2.0 = very large, 4.0 = extremely large.

3.4 Results

3.4.1 Participants

Out of the 37 participants recruited and enrolled in this study, 32 completed the entire study. Three participants dropped out of this study due to personal reasons, and two participants were removed due to not following the correct methodology.

Table 3.1 Demographic Characteristics			
Characteristics	Total	Boys	Girls

Subject number	32	20	12
Age (years)	11 ± 1.2	11 ± 1.293	11 ± 0.9
Height (cm)	153 ± 12	153 ± 13	153 ± 10
Weight (kg)	44 ± 12	43 ± 12	45 ± 12
Body Mass Index (BMI) (kg/m ²)	18 ± 3.1	18 ± 2.9	19 ± 3.4
Day one + two VM® Score (nm)	287 ± 82	280 ± 66	286 ± 107
Day one + two VM® Score (µmol/L)	1.6 ± 0.5	1.6 ± 0.4	1.6 ± 0.6
Ethnicity			
Māori	3	2	1
Tongan	2	2	0
European	26	16	10
Arab	1	0	1
Data given as mean ± standard deviation			

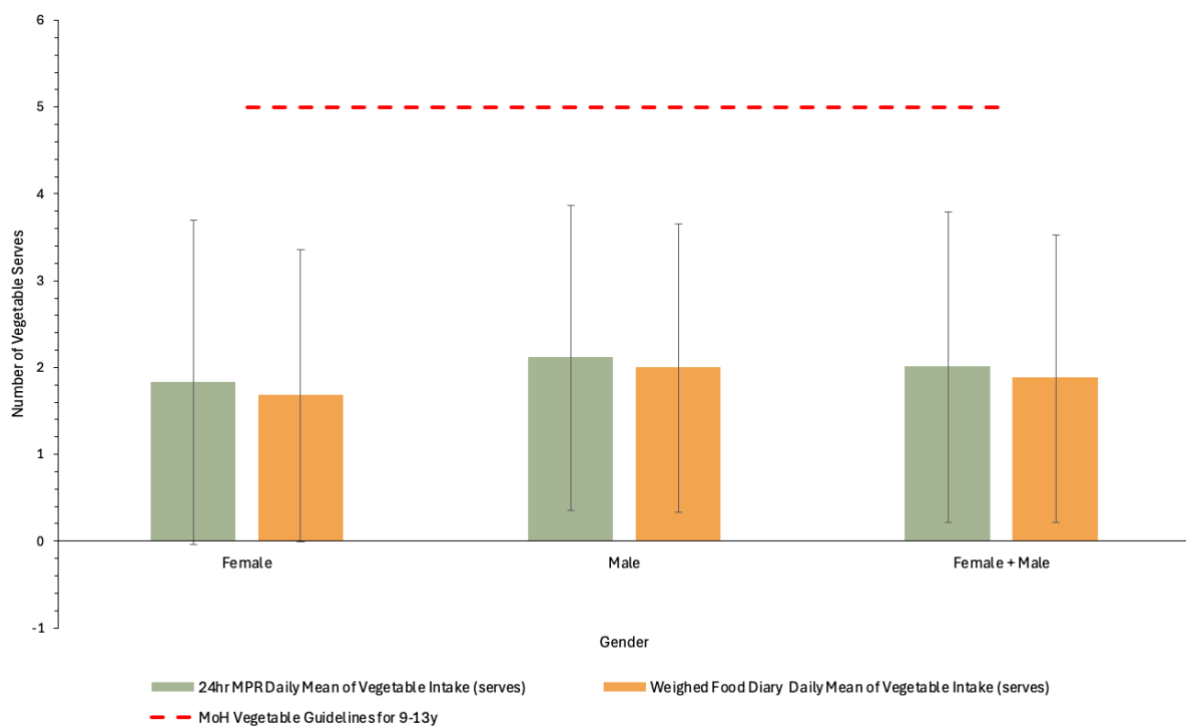
3.4.2 General Nutrient Intake

Girls between the ages of 9–13 years require 35 g/day of protein, while boys between the ages of 9–13 years require 40 g/day (Cormack, 2022). The estimated protein intake for both genders exceeded the recommended using the modified 24-hour MPR and weighed food diaries (Appendix B, Supplementary Table 1 to 6). The recommended dietary fibre intake for girls is 20 g/day and 24 g/day for boys (Cormack, 2022). This was met by both genders on most days for both methods except for the weekend modified 24-hour MPR intake (Appendix B, Supplementary Table 1 to 6). The daily recommended calcium intake for boys and girls is between 800-1050 mg/day (Cormack, 2022). Both genders met the recommended intake on most days, but girls fell short on more days (Appendix B, Supplementary Table 1 to 6). The recommended iron intake is 8 mg/day for boys and girls (Cormack, 2022). Both groups met the requirements across all days for both methods (Appendix B, Supplementary Table 1 to 6). The daily recommended sodium intake is 400-800 mg/day for both genders (Cormack, 2022). The average intake was more than three times the recommended amount across all days (Appendix B, Supplementary Table 1 to 6). The recommended carotenoid intake is 5340 µg/day for boys and 5040 µg/day for girls and neither gender met this. (Cormack, 2022). The

recommended daily energy intake per day for girls is between 7130-8770 kJ and 7623-9715 kJ for boys (Cormack, 2022). These recommendations were generally met; however, boys exceeded the recommended energy amount for the weekend weighed food recall (Appendix B, Supplementary Table 1 to 6).

3.4.3 Vegetable Intake

Both boys and girls, on average, did not meet the recommended vegetable intake of 5-5.5 serves a day for weekday and weekend modified 24-hour MPR and weighed food diaries (Figure 3.2). Boys did have a higher vegetable intake than girls (Figure 3.2). Vegetable intake was overestimated in the modified 24-hour MPR by both girls and boys (Figure 3.2). Children’s vegetable intake for the weekday modified 24-hour MPR and weighed food diaries was higher than their vegetable intake for the weekend (Appendix B, Supplementary Tables 1 to 6).



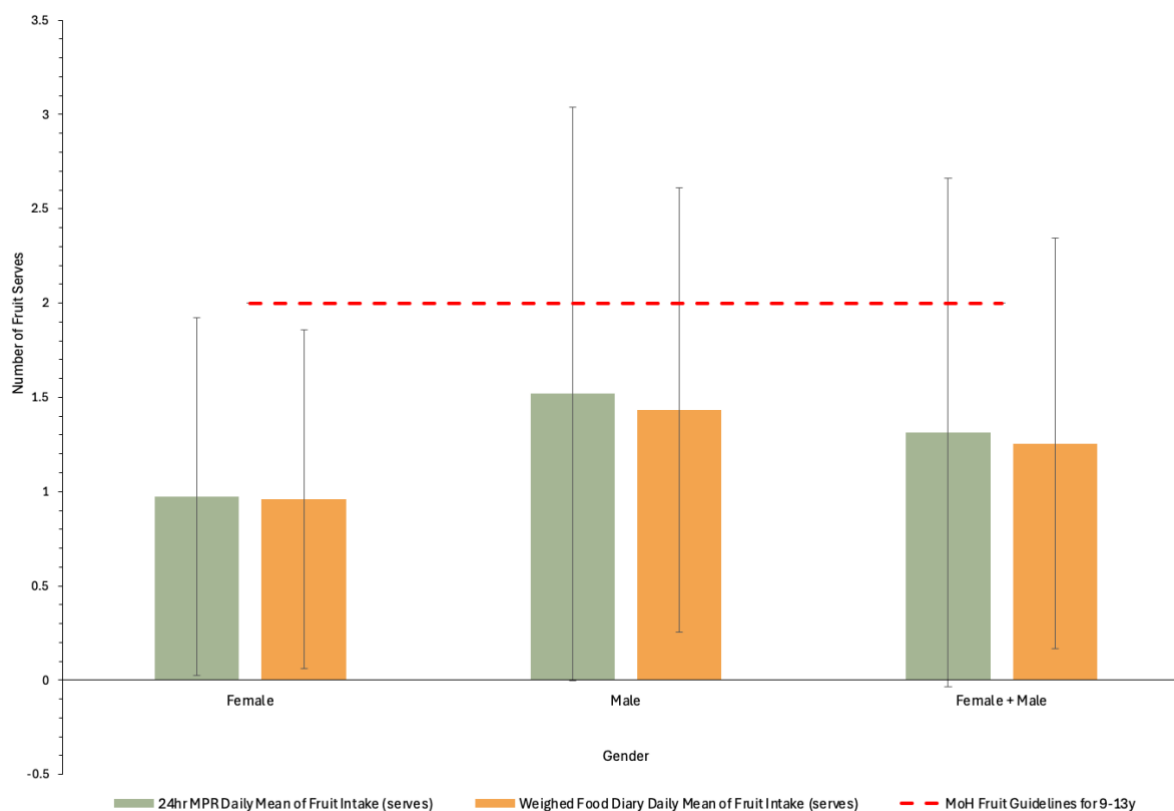
*Red dashed line = Ministry of Health Guidelines for Vegetable Servings for 9 to 13-year-olds

*Bars are raw means and standard deviation

Figure 3.2. Daily mean of vegetable intake as estimated from the modified 24-hour MPR and weighed food diary.

3.4.4 Fruit Intake

On average, boys and girls did not meet the recommended fruit intake of two serves for weekday and weekend modified 24-hour MPR and weighed food diary's, however, boys had an overall higher fruit intake than girls (Figure 3.3). Fruit intake was underestimated by girls and boys in the modified 24-hour MPR but was overestimated when looking at fruit intake in both boys and girls combined (Figure 3.3).



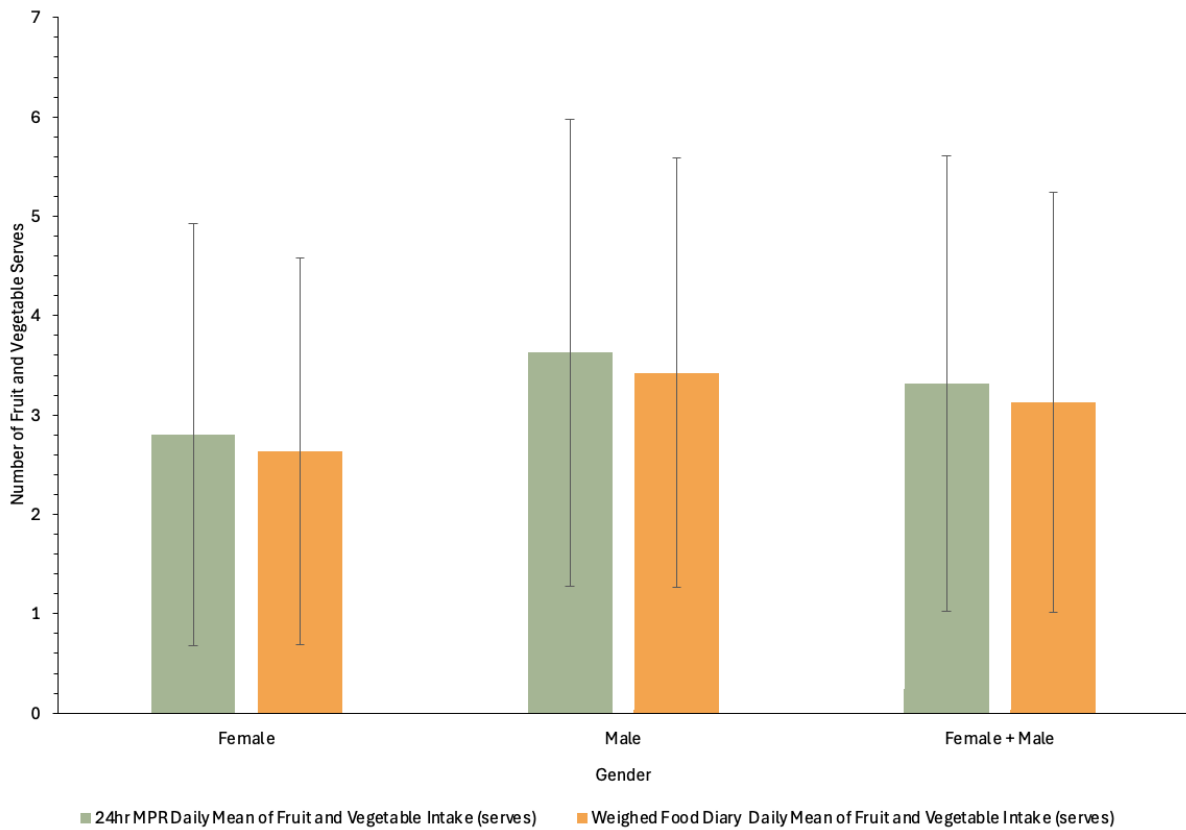
*Red dashed line = Ministry of Health Guidelines for Fruit Servings for 9 to 13-year-olds

*Bars are raw means and standard deviations

Figure 3.3. Daily mean of fruit intake as estimated from the modified 24-hour MPR and weighed food diary.

3.4.5 Total Fruit and Vegetable Intake

Total F/V intake for the weekday modified 24-hour MPR and weighed food diary had an overall higher estimated intake than the weekend (Appendix B, Supplementary Tables 1 to 6). Boys had an overall higher F/V intake than girls, but neither group met the recommended intake (Figure 3.4). Total F/V intake was overestimated in both girls and boys for the modified 24-hour MPR (Figure 3.4).



*Bars are raw means and standard deviations

Figure 3.4. Daily mean of fruit and vegetable intake as estimated from the modified 24-hour MPR fruit and weighed food diary.

3.4.6 Skin-carotenoid score vs median F/V intake from the modified 24-hour MPR and weighed food diaries

Figure 3.5 shows that there was no relationship between VM[®] SCS, the modified 24-hour MPR and the weighed food diary F/V intake. The relationship between the modified 24-hour MPR and weighed food diary shows some similarity (Figure 3.5).

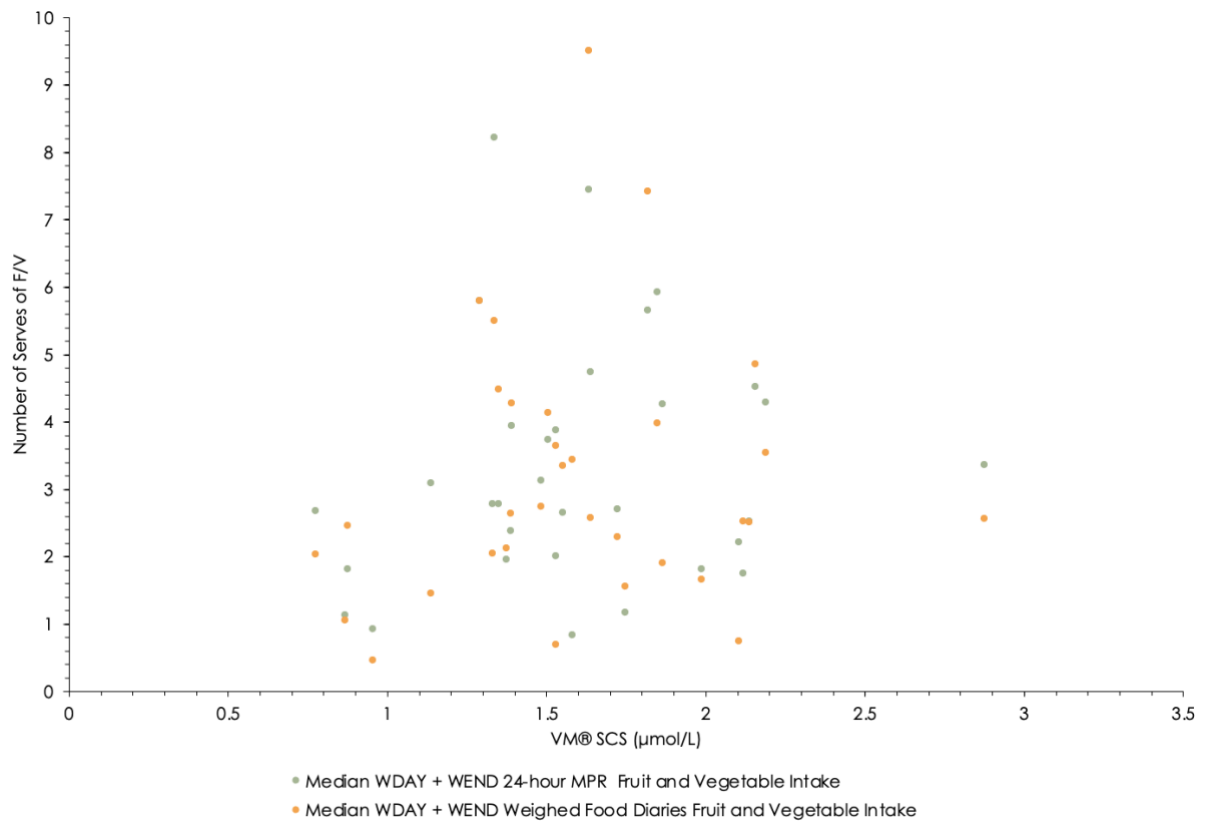


Figure 3.5. Skin-carotenoid score vs median fruit and vegetable intake as estimated from the modified 24-hour MPR and weighed food diaries.

3.4.7 Validity of the Modified 24-hour MPR Compared to Weighed Food Diaries

Table 3.2 Validity Measures								
Analysis Tool and Contrast Attribute	Log-Transformed Pearson Coefficient	Log-Transformed 90% Confidence Limits (r)	Raw Pearson Coefficient	Raw 90% Confidence Limits (r)	Standardised Log-Transformed Bias at X Value	Raw Bias at X Value	Standardised Log-Transformed Overall Mean Bias	Raw Overall Mean Bias
Carotenoids (µg)	WDAY: 0.84 WEND: 0.65 COMB: 0.82	WDAY: 0.72, 0.91 WEND: 0.44, 0.79 COMB: 0.69, 0.90	-	-	WDAY: -1.13 WEND: -2.31 COMB: -0.91	-	WDAY: -0.02 WEND: 0.06 COMB: 0.15	-
Total Fruit (serves)	-	-	WDAY: 0.76 WEND: 0.69 COMB: 0.80	WDAY: 0.61, 0.86 WEND: 0.49, 0.82 COMB: 0.66, 0.89	-	WDAY: 3.53 WEND: 2.40 COMB: 3.39	-	WDAY: 0.35 WEND: -0.28 COMB: 0.06
Total Vegetable (serves)	-	-	WDAY: 0.67 WEND: 0.66 COMB: 0.71	WDAY: 0.46, 0.81 WEND: 0.45, 0.80 COMB: 0.53, 0.83	-	WDAY: 1.55 WEND: 2.82 COMB: 1.07	-	WDAY: 0.04 WEND: 0.14 COMB: 0.09
Total F/V (serves)	-	-	WDAY: 0.71 WEND: 0.69 COMB: 0.78	WDAY: 0.52, 0.83 WEND: 0.50, 0.82 COMB: 0.63, 0.88	-	WDAY: 1.05 WEND: 1.36 COMB: 0.63	-	WDAY: 0.20 WEND: -0.06 COMB: 0.10
WDAY = weekday, WEND = weekend, COMB = combined (average of weekday and weekend), F/V = fruit and vegetables The modified Cohen scale values for bias at X value and overall bias: <0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, 2.0–4.0 = very large, >4.0 = extremely large. Values are 90% CI								

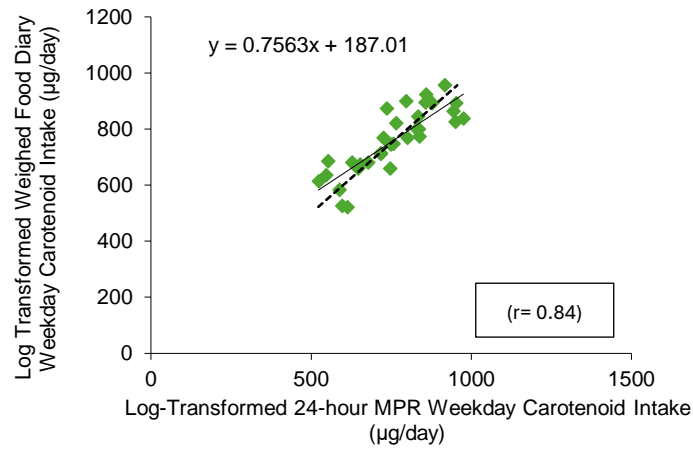


Figure 3.6. Correlation between log-transformed 24-hour MPR and weighed food weekday carotenoid intake ($\mu\text{g}/\text{day}$).

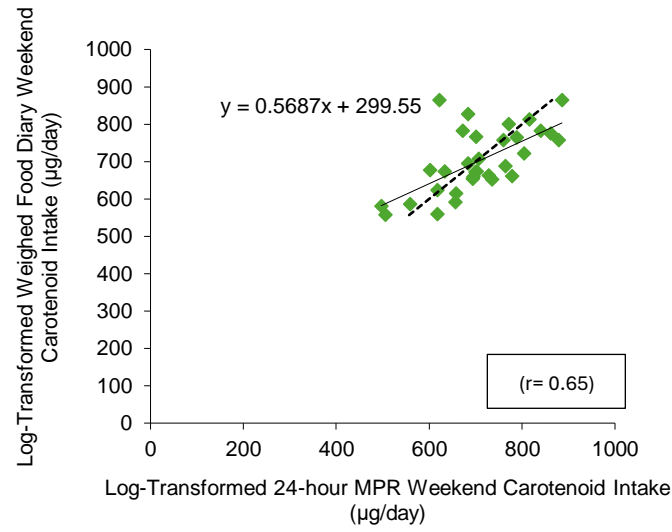


Figure 3.7. Correlation between log-transformed 24-hour MPR and weighed food weekend carotenoid intake ($\mu\text{g}/\text{day}$).

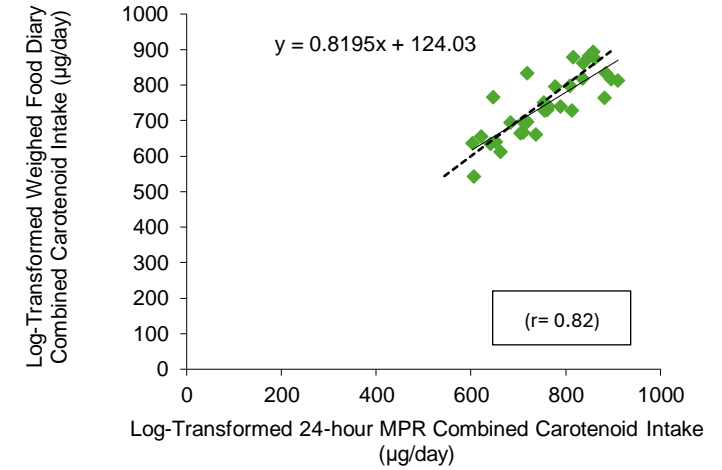


Figure 3.8. Correlation between log-transformed 24-hour MPR and weighed food combined carotenoid intake ($\mu\text{g}/\text{day}$).

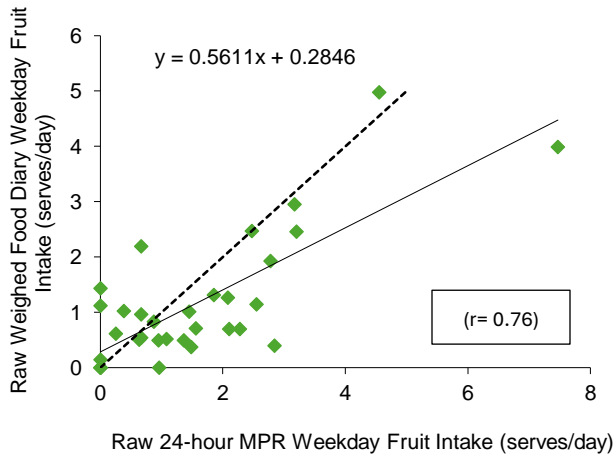


Figure 3.9. Correlation between raw 24-hour MPR and weighed food weekday fruit intake (serves/day).

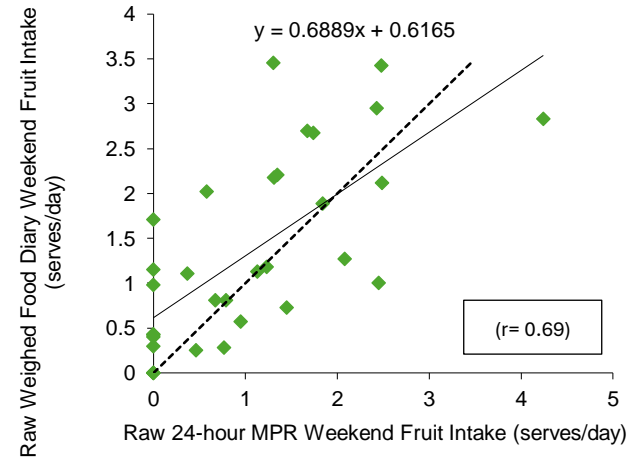


Figure 3.10. Correlation between raw 24-hour MPR and weighed food weekend fruit intake (serves/day).

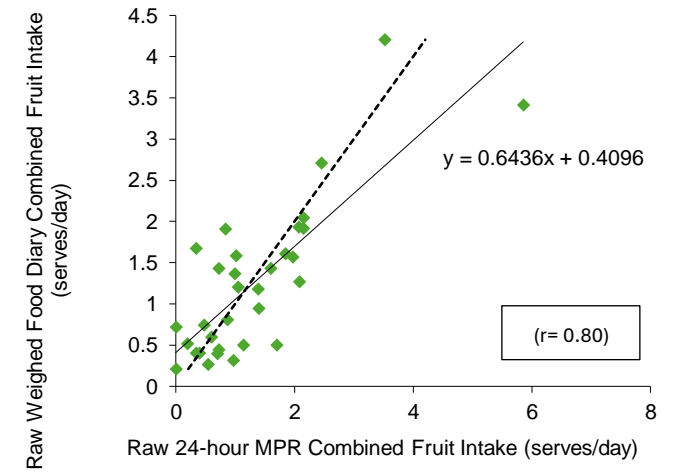


Figure 3.11. Correlation between raw 24-hour MPR and weighed food combined fruit intake (serves/day).

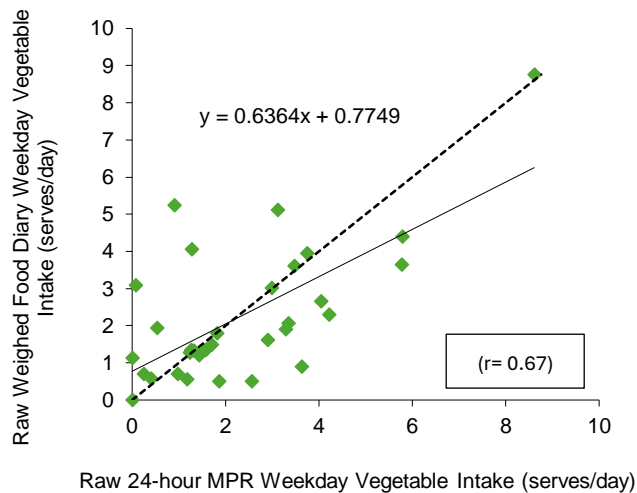


Figure 3.12. Correlation between raw 24-hour MPR and weighed food weekday vegetable intake (serves/day).

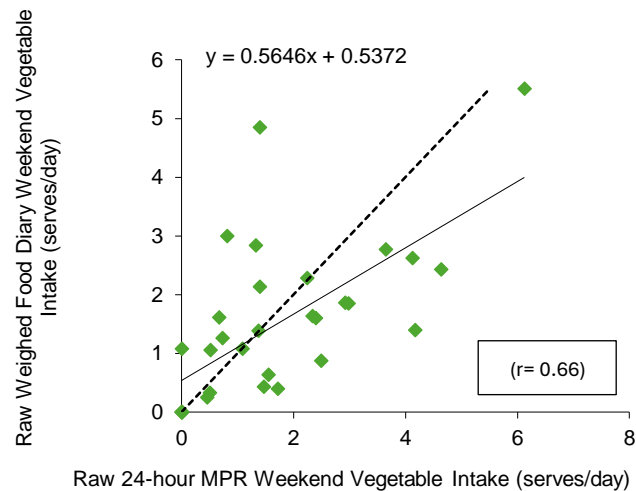


Figure 3.13. Correlation between raw 24-hour MPR and weighed food weekend vegetable intake (serves/day).

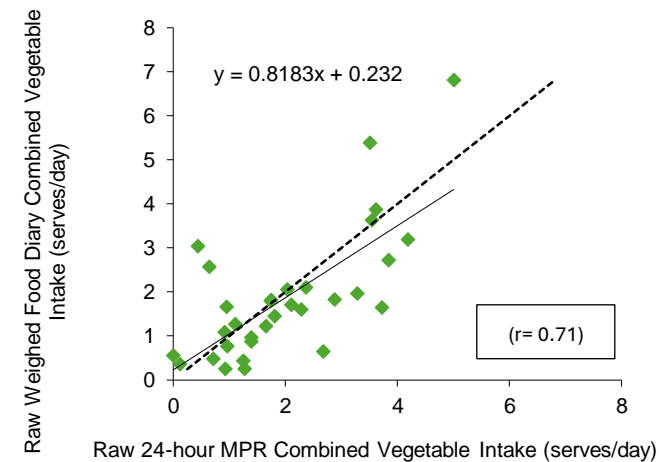


Figure 3.14. Correlation between raw 24-hour MPR and weighed food combined vegetable intake (serves/day).

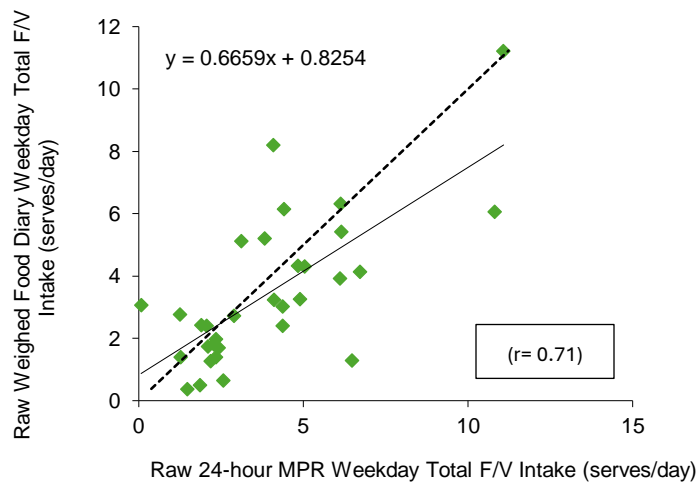


Figure 3.15. Correlation between raw 24-hour MPR and weighed food weekday total F/V intake (serves/day).

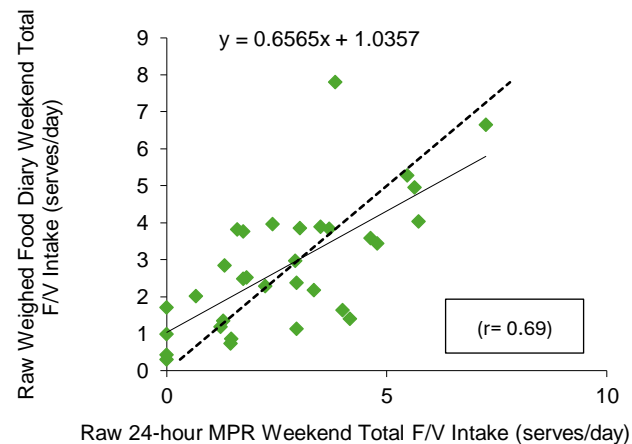


Figure 3.16. Correlation between raw 24-hour MPR and weighed food weekend total F/V intake (serves/day).

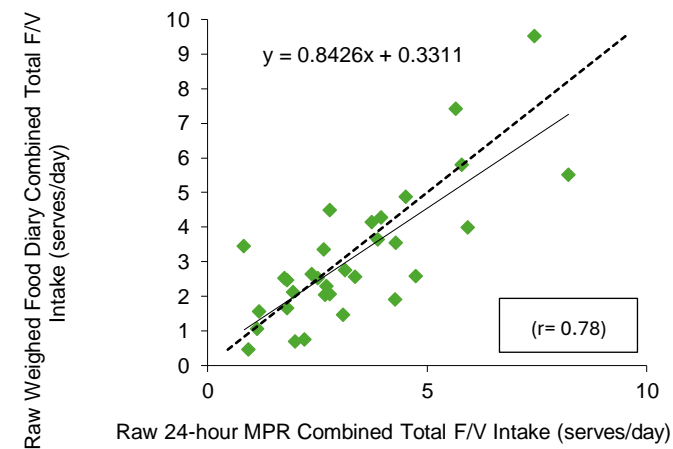


Figure 3.17. Correlation between raw 24-hour MPR and weighed food combined total F/V intake (serves/day).

3.4.7.1 Pearson Correlation for Validity

Table 3.2 and Figures 3.6 to 3.17 displays the Pearson correlations calculated from the comparison between the modified 24-hour MPR and weighed food diaries, which assessed the relationship between the two methods. The log-transformed Pearson correlation coefficient for carotenoids intake on all days was moderate to strong positive (Table 3.2). The raw Pearson correlation coefficient for total fruit intake was moderate to strong positive across intake of all days (Table 3.2). Total vegetable intake for all days was a moderate to strong positive correlation (Table 3.2). The Pearson correlation for total F/V intake on all days was moderate to strong positive (Table 3.2).

3.5.7.2 Bias at X Value for Validity

Table 3.2 presented the bias at X value, which provided a statistic for the level of agreement between the modified 24-hour MPR and weighed food diaries. The bias at X value was calculated by dividing the mean bias of the modified 24-hour MPR by the standard deviation of the weighed food diary. For carotenoids, the standardised log-transformed bias at X value was moderate in a positive direction on weekday and combined days and very large for weekends (Table 3.2). Standardised raw bias at X value for total fruit intake was very large in a positive direction across all days (Table 3.2). Vegetable intake, effect sizes were large on weekdays, very large on weekends and moderate on combined days, all in a positive direction (Table 3.2). Table 3.2 shows that total F/V intake was moderate in a positive direction on weekdays and combined intakes and large in a positive direction on weekend days.

3.6.7.3 Overall Mean Bias for Validity

Table 3.2 shows the values for standardised log-transformed overall mean bias which measured the difference between the modified 24-hour MPR and weighed food diaries. For carotenoid intake, the bias was trivial on all days, in a positive direction. The values for standardised raw overall mean bias for total fruit intake were small on weekdays and weekend intakes and trivial on combined days, all in a negative direction (Table 3.2). Total vegetable and total F/V intake were trivial across all days, in a positive direction (Table 3.2).

3.6.8 Reliability of the Modified 24-hour MPR Compared to Weighed Food Diaries and Reliability of the Veggie Meter®

Table 3.3 Reliability Measures

Analysis Tool and Contrast Attribute	Log-Transformed Change in Mean (%)	Standardised raw Change in Mean	Mean Log-Transformed Typical Error as a CV (%)	Log-Transformed 90% Confidence Limits (TEE)	Standardised Mean raw Typical Error	Raw 90% Confidence Limits (TEE)	Mean Log-Transformed Pearson Correlation	Log-Transformed 90% Confidence Limits (r)	Mean raw Pearson Correlation	Raw 90% Confidence Limits (r)	Mean Log-Transformed ICC	Log-Transformed 90% Confidence Limits (ICC)	Mean raw ICC	Raw 90% Confidence Limits (ICC)
<i>Veggie Meter®</i>														
Weekday VM® SCS (nm)	2-1: 1.01 3-2: 1.01	-	5.2	2-1: 3.3, 5.1 3-2: 5.1, 8.0	-	-	0.97	2-1: 0.97, 0.99 3-2: 0.93, 0.98	-	-	0.97	2-1: 0.97, 0.99 3-2: 0.93, 0.98	-	-
Weekend VM® SCS (nm)	2-1: 1.0 3-2: 1.2	-	4.0	2-1: 3.4, 5.2 3-2: 3.2, 4.9	-	-	0.98	2-1: 0.97, 0.99 3-2: 0.97, 0.99	-	-	0.99	2-1: 0.97, 0.99 3-2: 0.97, 0.99	-	-
Combined VM® SCS (within day) (nm)	2-1: 1.0 3-2: 1.0 4-3: -0.5 5-4: 1.0 6-5: 1.2	-	5.1	2-1: 3.3, 5.1 3-2: 5.1, 8.0 4-3: 5.5, 8.5 5-4: 3.4, 5.2 6-5: 3.2, 4.9	-	-	0.98	2-1: 0.97, 0.99 3-2: 0.93, 0.98 4-3: 0.92, 0.98 5-4: 0.97, 0.99 6-5: 0.97, 0.99	-	-	0.97	2-1: 0.97, 0.99 3-2: 0.93, 0.98 4-3: 0.92, 0.98 5-4: 0.97, 0.99 6-5: 0.97, 0.99	-	-
Between Day VM® SCS (nm)	2-1: 1.5 3-2: -0.5 4-3: 1.5 5-4: -0.5 6-5: 1.7	-	4.9	2-1: 3.5, 5.3 3-2: 3.5, 5.4 4-3: 2.9, 4.5 5-4: 5.1, 7.9	-	-	0.98	2-1: 0.97, 0.99 3-2: 0.97, 0.99 4-3: 0.98, 0.99 5-4: 0.93, 0.98	-	-	0.98	2-1: 0.97, 0.99 3-2: 0.97, 0.99 4-3: 0.98, 0.99 5-4: 0.93, 0.98	-	-

				6-5: 4.8, 7.4				6-5: 0.94, 0.98				6-5: 0.94, 0.98		
<i>Modified 24-hour MPR</i>														
Modified 24-hour MPR Carotenoid Intake (µg)	8.2	-	125.6	-	-	96.5, 180.6	-0.20	-0.50, 0.06	-	-	-0.20	-0.50, 0.05	-	
Modified 24-hour MPR vs Weighed Fruit Intake (serves)	-	-2.19	-	-	0.94	0.78, 1.19	-	-	0.12	-0.18, 0.40	-	-	0.12	-0.18, 0.40
Modified 24-hour MPR vs Weighed Vegetable Intake (serves)	-	-0.19	-	-	0.92	0.76, 1.17	-	-	0.16	-0.14, 0.44	-	-	0.16	-0.14, 0.43
Modified 24-hour MPR vs Weighed F/V Intake (serves)	-	-1.01	-	-	0.94	0.78, 1.19	-	-	0.13	-0.18, 0.41	-	-	0.12	-0.17, 0.40
WDAY = weekday, WEND = weekend, COMB = combined (average of weekday and weekend), VM [®] = Veggie Meter [®] , SCS = skin-carotenoid score, MPR = multiple pass recall Thresholds for raw change in mean and raw typical error for reliability were as follows: 0.2 = small, 0.6 = moderate, 1.2 = large, 2.0 = very large, 4.0 = extremely large. Values are 90% CI														

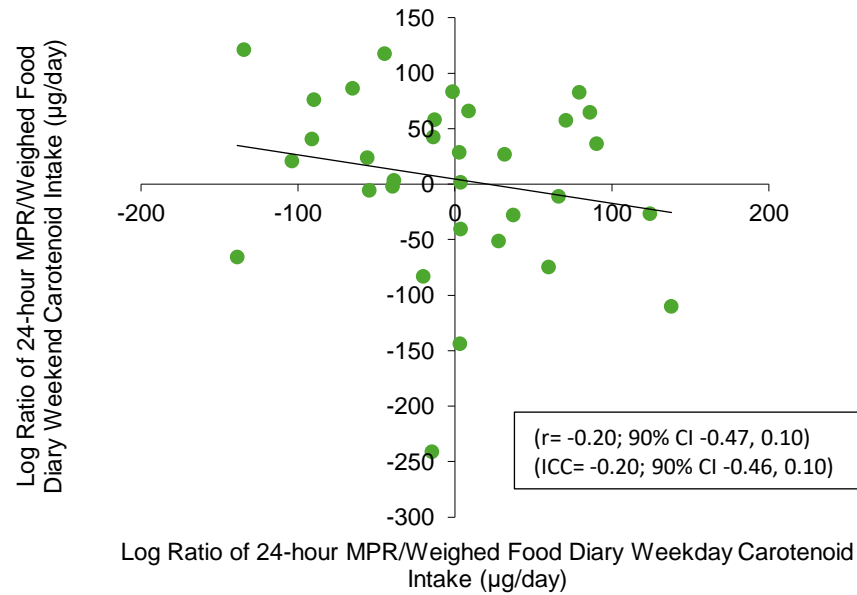


Figure 3.18. Correlation between log-transformed ratio of 24-hour MPR/weighed food diary on weekday and weekend for carotenoid intake as a measure of reliability.

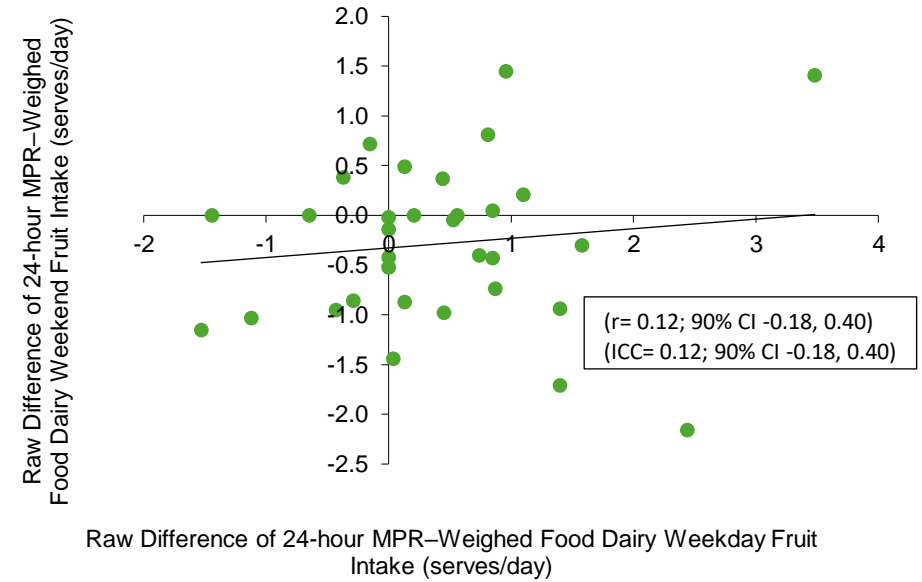


Figure 3.19. Correlation between raw difference of 24-hour MPR-weighed food dairy servings on weekday and weekend for fruit intake as a measure of reliability.

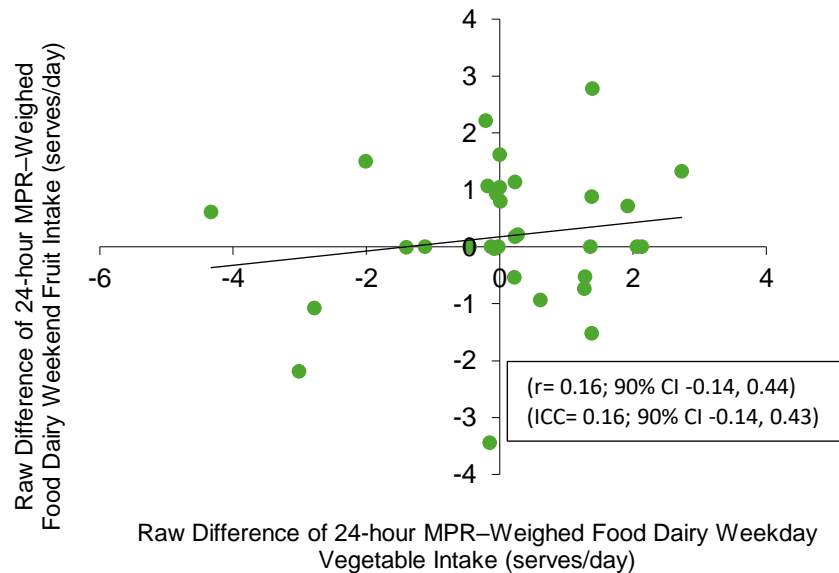


Figure 3.20. Correlation between raw difference of 24-hour MPR-weighed food diary on weekday and weekend for vegetable intake.

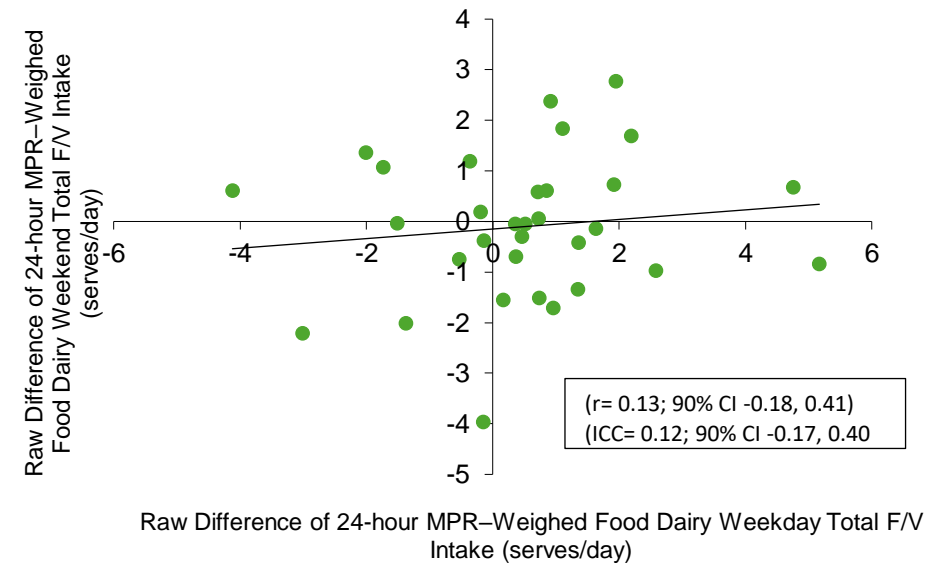


Figure 3.21. Correlation between raw difference of 24-hour MPR-weighed food diary on weekday and weekend for total F/V intake.

3.7.8.1 Change in Mean (%) for Reliability

Table 3.3 summarises the change in mean values derived from the VM[®] and the comparisons made between the modified 24-hour MPR and weighed food diaries of carotenoid and F/V intake across different days. The log-transformed percentage of change in mean for weekday, weekend, combined, and between-day (SCS measured on the weekday compared to SCS measured on the weekend) SCSs was small (Table 3.3). For the modified 24-hour MPR carotenoid intake, the log-transformed percentage of change in mean was a small negative value (Table 3.3). The standardised raw change in mean for the modified 24-hour MPR showed a very large negative value, while vegetable intake showed a small change in mean (Table 3.3). Total F/V displayed a very large change in standardised raw mean (Table 3.3).

3.8.8.2 Typical Error as a Coefficient of Variation (%) for Reliability

The data for typical error as a CV in Table 3.3 reflected the variability in estimation of intake between the modified 24-hour MPR and weighed food diaries. The mean log-transformed typical error as a percentage CV for weekdays, weekends, combined, and between-day SCSs was small (Table 3.3). The mean percentage log-transformed typical error as a CV for the modified 24-hour MPR carotenoid intake was large (Table 3.3). The standardised mean raw typical error for modified 24-hour MPR fruit, vegetable and total F/V intake ranged from moderate to large (Table 3.3).

3.9.8.3 Pearson Correlation for Reliability

Table 3.3 and Figures 3.18 to 3.21 displays the mean log-transformed and raw Pearson correlation for the estimates of F/V and carotenoid intake using the modified 24-hour MPR. The mean log-transformed Pearson correlation for weekday, weekend, combined, and between-day SCS had a strong positive correlation (Table 3.3). As seen in Table 3.3, the modified 24-hour MPR carotenoid intake had a weak negative correlation. The modified 24-hour MPR fruit, vegetable, and total F/V intake showed a weak positive correlation (Table 3.3).

3.10.8.4 Intraclass Correlation Coefficient for Reliability

Table 3.3 and Figures 3.18 to 3.21 displays the mean log-transformed and raw ICC for the estimates of F/V and carotenoid intake using the modified 24-hour MPR. The mean log-transformed ICC measures the consistency between the modified 24-hour MPR and weighed food diaries as seen on Table 3.3. The weekday, weekend, combined and between-day SCS showed excellent reliability (Table 3.3). In contrast, the mean log-transformed ICC for the modified 24-hour MPR carotenoid intake displayed poor negative reliability (Table 3.3). The mean raw ICC for the modified 24-hour MPR fruit, vegetable, and total F/V intake displayed poor reliability (Table 3.3).

3.5 Discussion

In the current study I aimed to determine the validity and reliability of a modified 24-hour MPR to evaluate carotenoid and F/V intake compared to weighed food diaries, and to estimate the reliability of the VM[®] tool for measuring skin carotenoid levels in 9 to 13-year-old school children living in Auckland. To the best of the writer's knowledge, a modified 24-hour MPR has not been validated against weighed food dairies in children in New Zealand, making this the first study to do so. Our results found that the modified 24-hour MPR was not a reliable measure of children's carotenoid, fruit, and vegetable intake compared to weighed food diaries. The VM[®], however, was found to be a reliable tool for measuring skin-carotenoid intake in 9 to 13-year-old school children. This study did however find that the 24-hour MPR was a valid tool to measure carotenoid, fruit and vegetable intake. There was a positive bias for estimated fruit, vegetable and carotenoid intake which would need to be adjusted to offset it.

3.5.1 Validity of the Modified 24-hour MPR Compared to Weighed Food Diaries

The modified 24-hour MPR was found to be a valid tool to estimate F/V and carotenoid intake compared to weighed food diaries. While no studies in the past have looked at the validity of 24-hour MPRs compared to weighed food diaries as the criterion to estimate F/V and carotenoid intake, studies have evaluated the general validity of 24-hour dietary recalls. Foster and Bradley (2018) looked at the validity of 24-hour dietary recalls in children aged 4–12 years against energy expenditure measured by doubly labelled water and found that that

multiple 24-hour dietary recalls were more accurate and valid to estimate food intake than a single 24-hour dietary recall. Although Foster and Bradley (2018) did not specifically look at F/V intake, they still provided an insight on validity of 24-hour MPRs on children.

The effect sizes for the standardised raw bias at X value for F/V intake estimated from the modified 24-hour MPRs ranged between moderate to very large which indicated overestimation of F/V intake. Overestimation of foods such as F/V is a display of a limitation of 24-hour MPRs (Gemming et al., 2014; Ralph et al., 2011). 24-hour MPRs are susceptible to under- or overreporting due to social desirability (Gemming et al., 2014; Ralph et al., 2011). This current study suggested that children may have overestimated their F/V intake to make their intake seem healthier or more appealing (Figure 3.4). The over-estimation in this current study can also be attributed to the reliance of children's memory and the challenges of estimating accurate portion sizes. Ralph et al. (2011) determined that 24-hour MPRs rely on memory which poses as a disadvantage as it can result in inaccurate information. Children between the ages of 9 to 13 do not often make their own meals, the children from this study had all their meals prepared by their parents/caregivers. Not actively choosing what they were eating meant that they would most likely pay less attention to what they ate which impacted reporting inaccuracies. In this study, on average, children over-estimated vegetable intake in the modified 24-hour MPR by two serves when compared to the weighed food diaries. This would need to be adjusted to remove the bias which can be done by subtracting two servings of vegetables from future modified 24-hour MPRs.

3.5.2 Relationship Between Carotenoid and F/V Intake Compared to the VM[®] SCS

Fruit and vegetable and carotenoid intake from this current study had no correlation with the VM[®]. Limited correlation between the VM[®] and the modified 24-hour MPR F/V and carotenoid intake may be due to the smaller sample size (Figure 3.5). Past studies had a sample size of 136 and 66 students whereas this study only had 32 children (Hasnin et al., 2023; Hasnin et al., 2024). While past studies have not compared the VM[®] against 24-hour MPRs, they have found significant correlations between VM[®] SCS and F/V intake using a FFQ (Hasnin et al., 2023; Hasnin et al., 2024). Hasnin et al. (2024) evaluated the evidence that validated the VM[®] against F/V consumption estimated by a FFQ among preschool children.

This study found a small but significant correlation between the VM[®] and total F/V intake, and they concluded that the VM[®] was a potentially valid and feasible tool to use (Hasnin et al., 2024). (Hasnin et al., 2023) assessed the validity of the VM[®] to estimate F/V intake in non-Hispanic preschool children and they found that F/V intake using an FFQ was significantly correlated with the VM[®] scores. A small effect size was also found for the validity of the VM[®], suggesting good validity (Hasnin et al., 2023).

3.5.3 Reliability of the Modified 24-hour MPR and Weighed Food Diaries

The modified 24-hour MPR showed poor reliability therefore high variability in the estimated intake of F/V and carotenoid intake. Poor reliability in this study was likely most attributable to the inaccurate reporting of the food intake over the two different days by children in the modified 24-hour MPR. This study did not control the food intake of children therefore could not control the day-to-day variability that occurred. The reliability for carotenoid intake from the modified 24-hour MPR suggested that a relatively large but not impractical samples size may be achievable for intervention studies looking at moderate standardised effects. Using standard type-1 and -2 error rates of 5% and 80% and the within-subject SD or TEE of 125.6%, the average between-subject SD of 110% and a moderate standardised difference as the effect size (0.6×110), the sample size for a parallel groups pre-post randomised controlled trial is 82 or 41 in the treatment and control group. Such interventions may be a doubling of daily F/V intake or a fortified food product.

Not many studies have looked at the reliability of 24-hour MPRs, but St. George et al. (2016) found that three 24-hour dietary recalls produced low reliability in children which aligns with the results of this current study. (St. George et al., 2016) also found that to achieve 80% accuracy, 21 to 32 24-hour MPRs should be conducted for fruit intake and 21 to 25 24-hour MPRs for vegetable intake, and this level of sampling is clearly not practical or economic.

3.5.4 Veggie Meter[®], F/V and Carotenoid Intake

The current reliability statistics for the VM[®] showed that the VM[®] was a highly reliable tool to measure SCS. This was determined by TEE as a percentage CV which indicated low variability between the six VM[®] scores over two different days. Boys and girls did not meet

the recommended daily intake of F/V. Boys were seen to consistently consume more F/V than girls and this correlated with a higher carotenoid intake.

Past studies have found that boys who consume greater amounts of F/V had a higher VM[®] SCS compared to girls (Burkholder et al., 2021; May et al., 2020). However, Nagao-Sato et al. (2021) found that while boys had an overall higher VM[®] SCS, girls had a higher F/V and carotenoid intake. This current study did not align with the findings of Burkholder et al. (2021) and Nagao-Sato et al. (2021) as boys had a lower SCS score than girls despite having a higher F/V and carotenoid intake. This current study did align with the past findings of (Takeuchi et al., 2022) where they found girls had a higher VM[®] SCS than boys.

This study found that VM[®] SCS was not influenced by an intake high in F/V and carotenoids. However, past studies have shown that as F/V intake increases, VM[®] SCS increases (Hasnin et al., 2023; Hasnin et al., 2024; Martinelli et al., 2021; May et al., 2020; Varghese et al., 2024). The lack of a correlation in this study may have been because of the small sample size (Figure 3.5).

On average, F/V intake was overestimated by both boys and girls. This again may be contributed to children wanting to make their diet seem healthier or socially acceptable which has been considered a limitation of 24-hour dietary recalls in the past (Gemming et al., 2014; Ralph et al., 2011).

3.5.5 Strengths and Limitations of the Study

Two main strengths identified in this study were, using standardised and appropriate training for the writer and research assistant. The second strength was the use of the Lilacs NZ food portion sizes — photographic atlas and measuring cups and spoons to provide visual aids for the children when estimating their food intake.

There were various limitations to using the weighed food diary as a criterion, such as children's unpredictable and variable eating habits or parents being overly aware of their children's food intake. There were also the previously known limitations of using the modified

24-hour MPR, such as dependence on children's memory and day-to-day variation. The last limitation was the outdated Lilacs NZ food portion sizes — photographic atlas, which didn't capture all the current and wide variety of meals and foods that New Zealand children eat in 2024.

3.6 Conclusion

In summary, this study demonstrated that the use of the modified 24-hour MPR was not a reliable tool for measuring F/V intake but was a valid tool in a sample of 9 to 13-year-old Auckland-based New Zealand children in 2024. The moderate to very large effect sizes of bias at X value in conjunction with trivial to moderate effect sizes for overall mean bias suggested high variability in modified 24-hour MPRs for estimating nutrient intake. Additionally, bias in the estimated intake of the modified 24-hour MPR suggested that it should be used with precaution. This study did suggest that fruit and vegetable intake was not met within the sample of children. Male participants did however have a greater F/V intake on average than female participants. We also found that the VM[®] had high reliability supporting its use as a tool to measure chronic carotenoid intake in children, although reliability measures within an intervention study would be required to validate the VM[®] as a reliable tool to track effects of changes in dietary intake on tissue levels. The findings in this study highlighted the challenges in assessing F/V intake in children and that many factors need to be considered.

Future studies should consider determining the validity and reliability of modified 24-hour MPR in a larger population of children in New Zealand. Other dietary intake tools such as an FFQ could also be tested for validation in New Zealand children. An addition of a wearable camera on children to observe food intake should be considered as it can make food intake recording more accurate, though this would pose ethical and privacy concerns that would need to be addressed. Fruit and vegetable choices made by boys and girls should be further studied to determine why one gender has a greater intake than the other. Lastly, future studies should evaluate the correlation between the VM[®] SCS and F/V intake in New Zealand children on a larger scale.

Chapter 4

4.0 Overview Conclusion and Recommendations

4.1 Overview

Adequate intake of F/V provides children with important nutrients contributing to their growth and development. However, children in New Zealand are not eating enough F/V (Ministry of Health, 2023b). Inadequate consumption of F/V can increase the risk of NCDs and some cancers (WHO, 2023). The last nutrition survey is outdated by over 20 years, which means a more recent study is required to determine children's eating patterns in the current climate. To the best of the writer's knowledge, no studies have been undertaken with New Zealand children looking at the validity and reliability of using a modified 24-hour MPR compared to weighed food diaries to determine F/V intake. Therefore, this study aimed to assess the validity and reliability of modified 24-hour MPRs. The results from this study will be used to determine if it is feasible to use a modified 24-hour MPR to collect food intake, particularly F/V intake in New Zealand children for future studies.

4.2 Main findings

Objective One: To compare the validity and reliability of the modified 24-hour MPR compared to weighed food diaries.

Findings: The modified 24-hour MPR was found to be a valid tool however, the raw and log-transformed bias at X value for fruit, vegetable, total F/V and carotenoid intake ranged between moderate to very large, which is an indication that the modified 24-hour MPR carotenoid, fruit, vegetable, and total F/V intake estimates deviated from the weighed food diary amounts. This suggested that the modified 24-hour MPR estimated fruit, vegetable, and carotenoid intake would need to be adjusted for. This can be done in future studies which use the modified 24-hour MPR by subtracting the bias. For example, in this study, on average children over-estimated vegetable intake by two serves. Therefore, future studies can reduce this bias by subtracting two servings of vegetables from the child's estimated intake, or the estimated correct amount at a sampled amount from the regression equation from the relationship between the criterion and the modified 24-hour MPR. The raw and log-transformed percentage change in the mean of weekday, weekend, and combined

days 24 carotenoid, vegetable, and F/V intake was at a high negative percentage, indicating underestimation. High percentage change in mean and high variability of the raw and log-transformed typical error as a percentage CV indicates that the modified 24-hour MPR was a relatively unreliable measure of F/V intake compared to weighed food diaries (CV 126%). To be a useful tool for research, the modified 24-hour MPR requires better reliability. Future research could investigate determining the validity and reliability of the modified 24-hour MPR with further modifications such as the addition of food frequency questionnaires, or other food intake tools, or the addition of wearable cameras to assess food intake, and in a larger population on children in New Zealand to improve estimate precision.

Objective Two: To determine the carotenoid intake of children.

Findings: Both boys and girls did not meet the daily recommendation of carotenoid intake in both weighed food diaries and modified 24-hour MPR for weekday and weekend intakes. The recommended intake for boys is 5340 µg/day and 5040 µg/day for girls, while this was not met, boys had an overall higher mean carotenoid intake on weekday and weekend intakes for both weighed food diaries and modified 24-hour MPRs. This was reflected in a higher F/V in boys in both recalls over weekday and weekend intakes. These findings are consistent with past studies, which found that boys had higher VM[®] SCS and total F/V intake (Burkholder et al., 2021; May et al., 2020; Nagao-Sato et al., 2021). Future research could investigate F/V choices in boys and girls and the influences of one gender having a greater intake than the other.

Objective Three: To compare VM[®] SCS to the modified 24-hour MPR and the weighed food diary's estimated fruit and vegetable intake.

Findings: There was no correlation between VM[®] SCS, the modified 24-hour MPR and the weighed food diary F/V intake (Figure 3.5). Past literature has shown that as F/V intake increases (Hasnin et al., 2023; Hasnin et al., 2024; Martinelli et al., 2021; May et al., 2020; Varghese et al., 2024), SCS increases. This, however, was not the case for this study, most likely due to the small sample size. Future research can aim to determine a correlation between VM[®] SCS and F/V intake in New Zealand children on a larger sample size.

4.3 Strengths

A strength of this study was the training of the researchers for the modified 24-hour MPR. The writer and a research assistant were trained in the same way on how to carry out a modified 24-hour MPR, what types of prompts to use, and how to use the Lilacs NZ food portion sizes — photographic atlas. This training ensured that each interview was consistent while acquiring appropriate and adequate information. Another strength was the use of the Lilacs NZ food portion sizes — photographic atlas and measuring spoons and cups as prompts. The Lilacs NZ food portion sizes — photographic atlas and measuring tools gave the children a visual aid when describing how much food they had throughout the day.

4.4 Limitations

The limitations of using a weighed food diary as a criterion were the increased the awareness parents would have had of their children's eating patterns. This could have led to a high likelihood of alterations being made to the children's diet to make their intake more healthy or appealing. Another limitation of using the weighed food diaries was the unpredictable eating patterns of their children and parent's inability to prevent the consumption of food outside of what they provide their children. Children gain more autonomy over their food consumption as they grow older, and because of this age group, the participants were likely to eat food outside of home, e.g., After school at the dairy or swapping foods with friends at lunch. Although we explicitly told the children and parents to avoid swapping foods at lunchtime or bring home wrappers of what they ate, children still ate what they were not given by their parents. Due to this, parents could not always accurately weigh and record what their children ate that day. It was also difficult for children to remember to tell their parents what they ate outside of home, which was another barrier to weighed food diaries. Another limitation of using weighed food diaries was the variability in using the scales. Parents of the children were told to weigh in grams, however, some parents used other measurements such as fluid ounce (fl. oz), which may have impacted the accuracy of measurements. Another limitation of the weighed food diaries was the high burden it posed on the parents. Due to it being time-consuming, it can affect accuracy if parents find recording too demanding. Inaccurate recording was seen in some weighed food diaries where parents

would forget to add brand names or specific details such as ‘1 cup salad’, with no detail on the contents of the salad.

The limitation of using the modified 24-hour MPR on children was the dependence on memory, many participants required a fair amount of prompting to help them remember what they ate, and even that was not enough at times. Another limitation of determining the reliability of the modified 24-hour MPRs was the day-to-day variation in food intake. Due to the variability, it was difficult to determine whether the modified 24-hour MPRs were reliable or not.

Another limitation was that the Lilacs NZ food portion sizes — photographic atlas was outdated, so it did not include many common foods such as chips, vegetable sticks, hummus, bars, popcorn, and meat patties. This meant that the writer and research assistant had to use examples of other foods, which was difficult for some children to pretend and imagine the substitute as the food they had eaten. This may have caused under or overestimation of some foods.

4.5 Recommendations

It would be important to familiarise the parents with more depth on how to use measuring scales. Another recommendation for tools that could be used as a criterion reference method instead of a weighed food diary are doubly labelled water for energy, parents providing photos of the meals with the weighed food diary, and having children observed during school meals by researchers. Another recommendation could be getting the children to wear a camera which captures their food intake throughout the day alongside a modified 24-hour MPR. We told parents to take photos of their child’s meals alongside the weighed food diaries, however, most parents failed to complete this. For this reason, another method could be providing the parents with a camera, which may make them more inclined to take photos as it would be on a separate device and makes it easier for the images to be provided to us. The decision to use a weighed food diary over other methods was that it was low in cost, could be carried out in a free-living situation, was easy of teach parents the method, time efficient, and the fact that it did not rely on memory. For these reasons, the weighed food diary was

justified over other methods, however, other methods could be used. The doubly labelled water for energy would have been expensive, taken more time, and required more training of the researchers. Observing children at school would be time-consuming and could be uncomfortable for the children being observed and may not be allowed by some schools or the Ministry of Education due to disruption and non-consent issues of non-participating children or parents. Having children wear a camera throughout the day and/or giving parents a camera to take photos of the meals would require access to cameras, and the parents and children would be required to be able to use the cameras. Having children wear camera can pose as ethical and privacy issues which would need to be considered and addressed. A way to determine the reliability of modified 24-hour MPRs would be to provide the participants with food to control their intake. The intake would be the same on the days measured, which would also allow reliability to be measured. While the Lilacs NZ food portion sizes — photographic atlas and measuring tools were useful, having food replicas/models would be beneficial. Food models are very realistic and can make it easier for children to identify how much they eat which can provide a more accurate representation of their food intake. The final recommendation is that a future study could use a known weighed diet record to validate the 24-hour MPR. By doing this, the precision of the estimated food intake using a 24-hour MPR increases.

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Appendices

Appendix A: Supplementary Methods

Table 1 Participant Recruitment Poster

Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ) Study



COLLEGE
OF HEALTH
TE KURA HAUORA TANGATA

WHAT IS THIS STUDY ABOUT?

Diet contributes to children's growth and development, educational performance and attainment, health and well-being. We are testing the feasibility and validity of a modified 24-hour dietary recall tool to understand the current food group and nutrient intake in New Zealand schoolchildren better.



Invitation to Parents and Children

WHO CAN JOIN?

Schoolchildren aged 9-13 years old and their parents/caregivers.



Scan me for more info and the sign up sheet!



WHAT WILL YOU HAVE TO DO?

Parents: Weigh or itemize food consumed by your child on 2 separate days (10-20 min)

Children: Recall their diet in the past 24 hours (10-20 min), place finger on the spectroscopy based device to measure carotenoids (e.g. Vitamin A) in the body, and have body weight and height measured (15 min).



INTERESTED?

Scan the QR code above or reach out to us through email or phone number and we will get in touch with you soon!

contact us by email: shalika.harshani@gmail.com or Tel: 02040084468

Participants who successfully complete the data collection will receive \$75 NZD in vouchers

This project has been reviewed and approved by the Massey University Human Ethics Ohu Matatika 1, Application OMI 23/46. If you have any concerns about the conduct of this research, please contact the Chairperson, Massey University Human Ethics Ohu Matatika 1, email humanethics1@massey.ac.nz.

Table 2 Participant Information Sheet



COLLEGE
OF HEALTH
TE KURA HAUORA TANGATA

Enhancing Dietary Assessment for New Zealand Schoolchildren (EDANZ): Reliability and Validity of a Modified 24-h Food Recall for Accurate Nutrition Monitoring

24 HOUR DIETARY RECALL PARTICIPANT INFORMATION SHEET

Researcher Introduction

We are researchers from Massey University with expertise in nutrition and physical activity.

Background and Invitation to Participate in Research Study

A healthy, balanced diet makes an important contribution to children's growth and development, their educational performance and attainment and their long-term health and well-being. However, obesity rates and aspects of malnutrition continue to increase and remain a problem in New Zealand and globally. The last nutrition survey in New Zealand school-aged children was done in 2002, meaning new up-to-date data is required to provide objective evidence to qualify diet change and to inform policy. Therefore, this study tests modifications and refinements to an existing tool for assessing what a child has eaten over the past 24 hours for its ability to correctly identify what foods were consumed. Having the correct information about what was eaten means that researchers can find out what nutrients an individual has consumed. The tool (interviewer-led 24-hour multiple pass recall) is used by a trained interviewer who will sit down with a child and ask them questions to help them remember what they ate in the last 24 hours in as much detail as possible.

The results from this study will be used to decide whether the improved 24-hour dietary recall tool for collecting information about what has been eaten by NZ schoolchildren does a good job of correctly estimating what was actually eaten. If the tool is found to be successful, it will be used in studies checking whether programmes designed to improve children's food and nutrition choices have been successful and whether they should continue to be funded.

We would like to invite you as a parent or caregiver and your child to take part in this assessment.

Participant recruitment

We are collecting dietary data from schoolchildren aged 9 to 13 from selected schools sampled across the Auckland region. Dietary recall can be challenging for some students, and other research has found that parental assistance enhances reliability. Therefore, we ask you, as their parents/guardian, to help them complete the two dietary interviews.

Project Procedures and Participant Involvement

- Parents and students will receive an initial letter of invitation to participate in three face-to-face data collection sessions. There will also be an expression of interest and a follow-up phone call to schedule an in-person meeting. One of the face-to-face data collection will be conducted twice, with different interviewers. The date, time and venue will be arranged according to the agreement of the particular parent and student, considering their availability.
- Instructions will be provided to the parent. The diet assessment day will be randomly allocated across candidate days.
- The meeting location will be decided according to the preferences of the parents and students.
- Each 24-hour diet recall interview session will take between 20 to 30 minutes.

During the interview

- Three trained post-graduate researchers will deliver the 24-hour multiple-pass recall protocol by interview.
- The first pass will involve the researcher recording a quick list of all food and drink consumed that the parent or guardian could remember.
- The second pass will involve the researcher going through each item on the quick list to compile a detailed list. Researchers will prompt the parent/guardian on specific details such as the time, place, description of the food, brand, and amount. Also, if you are happy to photograph the meal, it will help remind them of what your child eats during the 24-hour recall. Those photos will be utilised in this step as a prompt. Measurement aids (16cm x 16cm grids, 4-16cm circles, household measuring cups and spoons) will be used to determine consumed portions.
- The third pass will involve the researcher reading the detailed list back to the parent or guardian, allowing them to fill in any missing details. Recipes will be recorded at the end of the process, where relevant.

Each parent-child pair will receive NZ\$200 reimbursement (as a gift voucher) at the end of the data collection period as koha and recognition for their contribution to the study. In addition, A school will receive a NZ\$200 gift voucher (koha) for their participation.

Data analysis

We would like to assess dietary intake during two weekdays (school days) and one weekend day. Therefore, we will use a unique identifier to connect the responses for each student. However, consistent with the confidentiality and non-identity of a participant, we will not provide personal data to your child's school, the Ministry of Education or any other external party who will receive the dataset or results. All data will be deidentified, and a unique study code will connect the participant.

Participant's Rights

You or your child are under no obligation to accept this invitation. Your child's participation or non-participation will not influence his/her standing in the school. If you give consent for your child to participate, they have the right to:

- Decline to answer any particular question.
- Withdraw from the evaluation at any time, even after you have signed a consent form (if you or your child choose to withdraw, you cannot withdraw his/her data from the analysis after the data collection has been completed.).
- Ask any questions about the evaluation at any time during the participation.
- Provide information on the understanding that your child's name will not be used in any publications.
- Be given access to a summary of the project findings when it is concluded.

Good Practice and Cultural Safety for Massey University Research

- We acknowledge the concept of respecting the participant’s inherent dignity and acting in a caring manner towards them by way of:
- Taking full responsibility for performing the data collection in a safe and ethical manner
- Providing the participants with all of the critical information regarding the study in a clear way so that they can make informed decisions
- An awareness of the cultural significance and sensitivity to culturally safe implementation of the project
- Respect for the privacy and confidentiality of participants

Confidentiality

All data collected will be used solely for research purposes. Findings will be presented at conferences and submitted for publication in journals. A summary infographic will be provided to the participating schools and will be available to participants on request. All personal information will be kept confidential by assigning numbers to each participant. No names will be visible on any papers on which you provide information. All data/information will be dealt with confidentiality and will be stored in a secure location for 10 years at the School of Sport, Exercise and Nutrition, College of Health, Massey University, Albany Campus. After this time, an appropriate staff member from the School of Sport, Exercise and Nutrition will dispose of it.

Project Contacts

If you have any questions regarding this evaluation, please do not hesitate to contact either of the following people for assistance:

Name	Title	email Address	Contact Number
Ms. T.S.H. Perera School of Sport, Exercise and Nutrition, Massey University	Investigator (PhD Candidate)	harshani.perera.1@uni.massey.ac.nz	(02) 040084468
Varshika Patel	Research assistant	V.V.Patel@massey.ac.nz	XXX
Sarah McArley	Research assistant	S.M.McArley@massey.ac.nz	XXX
Prof David Rowlands School of Sport, Exercise and Nutrition, College of Health, Massey University, New Zealand	Supervisor Professor of Nutrition, Metabolism and Exercise	D.S.Rowlands@massey.ac.nz	(09) 9793295
Prof Aj Ali School of Sport, Exercise and Nutrition, College of Health, Massey University, New Zealand	Co-Supervisor Professor of Sport and Exercise Science	A.Ali@massey.ac.nz	(09) 2136414
Prof Carol Wham School of Sport, Exercise and Nutrition, College of Health, Massey University, New Zealand	Co-Supervisor Professor of Public Health Nutrition	C.A.Wham@massey.ac.nz	(09) 2136644

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics

Committee: Northern, Application NOR 23/XX. If you have any concerns about the conduct of this research, please contact Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800, x 43347, email humanethicsnorth@massey.ac.nz .

**Thank you for taking part in this
research.**

Table 3 Participant Consent Form

Child Identifier:



***Enhancing Dietary Assessment for New Zealand Schoolchildren
(EDANZ): Reliability and Validity of a Modified 24-h Food Recall
for Accurate Nutrition Monitoring***

**24 HOUR DIETARY RECALL
CONSENT FORM**

This consent form will be held for a minimum of Ten (10) years.

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

I understand that I have the right to withdraw my child from the evaluation and to decline to answer any particular questions (if I/they choose to withdraw I/we cannot withdraw his/her data from the analysis after the data collection has been completed).

I agree for my child to provide information to the researcher on the understanding that his/her name will not be used without my permission (the information will be used only for this project and publications arising from this study).

I agree for my child to participate in the 24 hours dietary recall under the conditions set out in the 24-h dietary recall Information Sheet.

I agree to give my child's dietary information during the 24 hours dietary recall interview under the conditions set out in the 24-h dietary recall Information Sheet.

I agree to allow researchers to measure the carotene level of my child's finger under the conditions set out in the Veggie meter Information Sheet.

I agree to keep weighed records of my child's meals within 24 hours on behalf of my child under the conditions set out in the weighed record Sheet.

I agree to take photographs of my child's meal under the conditions set out in the 24-h dietary recall Information Sheet.

Parents Name: **Signature:**

Child Full Name:

School: **Room number:**

Phone Number: **Date:**

Table 4 Questionnaire for Veggie Meter ® Foods

Questionnaire for Veggie Meter Foods

(The researcher will fill this out when the Veggie meter reading is taken.)

Date:

01. Age:

02. Height:cm

03. Weight:kg

04. Gender:

05. Ethnicity:

Choose the best answer by placing a circle around it according to the child's answer.

06	Are there any foods that you <u>do not</u> eat?	Yes	No	Don't Know		
	If yes, what are they?					
07	Do you eat liver (including liver pate)?	Yes	No	Don't Know		
	If yes, how often	every day	most days	every week	every month	once a year
08	Do you eat eggs ?	Yes	No	Don't Know		
	If yes how often	every day	most days	every week	every month	once a year
09	Do you take any vitamin supplements ?	Yes		No		
	If yes, name the supplement					
	If yes how often					

Vegetables and fruits

A serving is a handful. It can be fresh, frozen or canned. Do not count fries or hot chips as a vegetable.

10	How many servings of vegetables do you eat in one day ?									
	0	1	2	3	4	5	6	7	7+	Don't Know
11	How many servings of fruit do you eat in one day ?									
	0	1	2	3	4	5	6	7	7+	Don't Know
	Which vegetables?									
12	How many servings of carrot or pumpkin or do you eat in one week ?									
	0	1	2	3	4	5	6	7	7+	Don't Know
13	How many servings of dark green leafy vegetables (silver beet, spinach) do you eat in one week ?									
	0	1	2	3	4	5	6	7	7+	Don't Know
14	How many servings of tomatoes (fresh, canned, concentrated) do you eat in one week ?									
	0	1	2	3	4	5	6	7	7+	Don't Know

Table 5 *The Modified 24-hour MPR First Pass*

**Multiple Pass 24h Dietary Recall
Quick List**

Time	Food Item

Table 6 *The Modified 24-hour MPR Second Pass*

**Stage Two- Detailed List
Multiple Pass 24h Dietary Recall**

Location	Time	Description Product name Home-made or retail Cooking method	Amount Served	Brand	Leftover	To be completed by nutritionist	
						Food Group	Weight

Table 7 *Weighed Food Diary*

Date _____ **DAY 1**

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

Appendix B: Supplementary Results

Table 1 Weekday Modified 24-hour MPR Food Intake

Nutrient Intake	Total Weekday					Boys					Girls				
	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max
Energy (kJ)	8967	8628	2149	4573	15591	9200	8470	1916	7467	15591	8578	9283	2531	4573	12627
Carbohydrate (g)	253.2	245.7	60.04	138.9	415.7	257.5	247.5	52.36	188.1	415.7	246.1	221.1	73.05	138.9	396.5
Protein (g)	87.46	86.82	31.22	32.65	171.0	91.05	85.42	28.80	50.69	171.0	81.47	88.08	35.36	32.65	139.3
Total fat (g)	81.21	75.54	25.85	30.36	148.5	83.28	76.91	23.60	50.67	148.5	77.76	72.45	30.01	30.36	129.8
Saturated fat (g)	33.35	32	11.67	4.68	57.97	33.39	32	8.590	15.62	48.74	33.30	31.84	16.01	4.68	57.97
Dietary fibre (g)	24.87	24.71	9.837	9.65	54.95	27.28	27.77	10.38	13.6	54.95	20.85	23.31	7.651	9.65	31.08
Carotenoids (µg)	3862	1855	4539	186.3	17179	4033	1920	4519	234.9	17179	3577	1855	4758	186.3	13553
Sodium (mg)	2955	2825	1205	1145	5733	2938	2891	1113	1263	5733	2984	2825	1397	1145	5270
Calcium (mg)	931.7	922.4	492.7	134.4	1842	914.9	857.8	498.4	250.6	1654	959.8	952.6	503.5	134.4	1842
Iron (mg)	12.05	11.33	6.484	3.3	35.2	12.03	11.11	6.732	3.3	35.2	12.08	11.60	6.341	3.47	24.1
Fruit (serves)	1.573	1.225	1.583	0	7.47	1.808	1.425	1.802	0	7.47	1.183	0.81	1.089	0	3.17
Vegetable (serves)	2.351	1.755	1.944	0	8.61	2.332	2.07	2.031	0	8.61	2.383	1.755	1.879	0	5.78
Total F/V (serves)	3.924	3.47	2.527	0.07	11.08	4.139	3.965	2.818	0.07	11.08	3.565	2.38	2.014	1.26	6.72

Table 2 Weekend Modified 24-hour MPR Food Intake

Nutrient Intake	Total Weekday					Boys					Girls				
	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max
Energy (kJ)	8885	8259	2571	3135	14404	9153	8403	2371	6421	14404	8439	7936	2928	3135	12862
Carbohydrate (g)	245.4	245.1	84.40	96.39	445.8	258.2	251.13	81.46	133.9	445.8	224.1	220.0	88.43	96.39	412
Protein (g)	82.17	82.15	30.70	24.09	164.9	90.27	86.05	30.83	33.13	164.9	68.68	75.21	26.41	24.09	113.7
Total fat (g)	85.08	79.8	30.02	25.65	170.9	81.45	74.11	22.91	27.63	120.0	91.14	89.10	39.60	25.65	170.9
Saturated fat (g)	34.40	34.23	12.71	5.29	62.67	33.86	32.85	10.72	10.17	59.96	35.29	35.69	15.99	5.29	62.67
Dietary fibre (g)	21.98	19.41	8.698	11.5	47.28	23.31	20.61	9.245	12.91	47.28	19.77	16.45	7.553	11.5	32.86
Carotenoids (µg)	1815	1093	1803	143.7	7020	2058	1305	1782	143.7	6542	1409	979.1	1841	157.0	7020
Sodium (mg)	2471	2313	817.9	1149	4138	2501	2528	757.2	1260	4138	2421	2245	943.7	1149	4134
Calcium (mg)	713.8	583.4	399.4	68.83	1552	773.2	710.5	424.1	154.5	1552	614.8	580.1	348.9	68.83	1248
Iron (mg)	11.23	9.885	5.561	1.74	28.06	11.83	10.46	5.588	3.63	28.06	10.24	9.545	5.612	1.74	21.06
Fruit (serves)	1.056	0.87	1.039	0	4.24	1.23	1.07	1.147	0	4.24	0.765	0.86	0.790	0	2.49
Vegetable (serves)	1.65	1.38	1.577	0	6.12	1.889	1.435	1.452	0	4.64	1.273	0.51	1.763	0	6.12
Total F/V (serves)	2.714	2.66	1.868	0	7.25	3.119	3.225	1.694	0	5.73	2.038	1.565	2.022	0	7.25

Table 3 Average of Weekday and Weekend Modified 24-hour MPR Food Intake

Nutrient Intake	Total Weekday and Weekend Recall					Boys					Girls				
	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max
Energy (kJ)	8926	8470	2351	3135	15591	9176	8470	2128	6421	15591	8509	8726	2678	3135	12862
Carbohydrate (g)	249.3	245.7	72.76	96.39	445.8	257.9	249.8	67.59	133.9	445.8	235.1	221.1	80.11	96.39	412
Protein (g)	84.82	83.91	30.83	24.09	171.0	90.66	85.42	29.45	33.13	171.0	75.08	78.88	31.21	24.09	139.3
Total fat (g)	83.15	76.91	27.86	25.65	170.9	82.37	75.54	22.98	27.63	148.5	84.45	83.24	35.04	25.65	170.9
Saturated fat (g)	33.88	32.85	12.12	4.68	62.67	33.62	32.28	9.589	10.17	59.96	34.294	33.75	15.68	4.68	62.67
Dietary fibre (g)	23.43	23.27	9.325	9.65	54.95	25.30	23.73	9.906	12.91	54.95	20.31	19.82	7.455	9.65	32.86
Carotenoids	2838,	1426	3578	143.7	17179	3045	1646	3535	143.7	17179	2493	1037	3698	157	13553
Sodium (mg)	2713	2555	1050	1145	5733	2719	2596	965.4	1260	5733	2703	2383	1201	1145	5270
Calcium (mg)	822.7	778.5	458.2	68.83	1842	844.0,	811.8	462.4	154.5	1654	787.3	656	458.9	68.83	1842
Iron (mg)	11.64	10.65	6.006	1.74	35.2	11.93	10.89	6.108	3.3	35.2	11.16	10.1	5.931	1.74	24.1
Fruit (serves)	1.314	1.02	1.354	0	7.47	1.519	1.36	1.519	0	7.47	0.974	0.86	0.954	0	3.17
Vegetable (serves)	2.004	1.45	1.791	0	8.61	2.110	1.51	1.757	0	8.61	1.828	1.375	1.870	0	6.12
Total F/V (serves)	3.319	2.935	2.287	0	11.08	3.629	3.595	2.352	0	11.08	2.802	2.26,	2.122	0	7.25

Table 4 Weekday Weighed Food Diary Intake

Nutrient Intake	Total Weekday					Boys					Girls				
	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max
Energy (kJ)	8759	8905	2397	3838	13748	9224	8994	2289	5334	13748	7984	8561	2467	3838	11488
Carbohydrate (g)	246.9	239.6	74.16	88.43	412.7	254.9	239.6	68.23	159.2	412.7	233.4	226.2	84.50	88.43	346.9
Protein (g)	79.58	78.67	29.96	31.17	184.1	86.63	79.15	29.91	44.36	184.1	67.83	64.80	27.26	31.17	123.1
Total fat (g)	82.30	80.44	26.31	44.2	153.5	87.65	88.33	27.51	44.62	153.5	73.39	69.47	22.47	44.2	117.4
Saturated fat (g)	33.60	31.27	12.22	11.99	61.28	35.85	34.63	11.51	17.32	61.28	29.84	27.99	12.95	11.99	54.16
Dietary fibre (g)	26.10	23.57	10.68	5.57	47.29	28.72	26.22	10.32	11.21	47.29	21.72	20.29	10.20	5.57	40.18
Carotenoids (µg)	3411	2181	3402	186.1	14199	3926	2616	3743	191.5	14199	2554	1743	2670	186.1	8035
Sodium (mg)	2689	2316	1042	1006	5693	2874	2555	1091	1682	5693	2381	2189	914.9	1006	4070
Calcium (mg)	1086	930.0	530.2	114.7	2564	1157	935.7	570.1	542.8	2564	967.8	858.1	454.3	114.7	1923
Iron (mg)	13.03	12.68	4.963	3.19	24.94	13.67	12.68	4.485	7.74	23.13	11.95	11.53	5.715	3.19	24.94
Fruit (serves)	1.167	0.77	1.161	0	4.98	1.347	1.04	1.336	0	4.98	0.868	0.66	0.751	0	2.96
Vegetable (serves)	2.271	1.71	1.851	0	8.76	2.338	1.915	2.020	0	8.76	2.16	1.41	1.610	0.5	5.24
Total F/V (serves)	3.438	2.9	2.386	0.38	11.23	3.684	3.165	2.535	0.38	11.23	3.028	2.205	2.156	0.5	8.2

Table 5 Weekend Weighed Food Diary Intake

Nutrient Intake	Total Weekday					Boys					Girls				
	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max
Energy (kJ)	9169	8717	2403	4606	13628	9946	9503	2307	6387	13628	7873	8113	2037	4606	11285
Carbohydrate (g)	253.5	256.0	64.70	151.9	411.8	267.9	279.2	68.98	151.9	411.8	229.4	226.6	50.61	160.2	304.8
Protein (g)	86.38	79.61	38.80	24.99	214.8	97.42	84.54	40.33	36.72	214.8	67.98	59.20	28.99	24.99	115.0
Total fat (g)	87.53	81.65	30.54	29.44	158.0	96.16	88.17	29.82	46.42	158.0	73.14	74.38	27.03	29.44	115.1
Saturated fat (g)	35.31	34.18	13.28	15.1	68.84	38.96	37.66	14.02	20.5	68.84	29.22	30.59	9.638	15.1	43
Dietary fibre (g)	24.88	22.77	9.766	9.53	62.06	27.27	23.79	10.92	16.83	62.06	20.91	21.1	5.935	9.53	28.28
Carotenoids (µg)	1589	911.1	1432	261.8	5673	1706	1262	1288	268.7	5596	1394	702.7	1687	261.8	5673
Sodium (mg)	3026	2723	1169	1080	6107	3297	3191	1154	1796	6107	2574	2504	1093	1080	5010
Calcium (mg)	951.8	800.0	453.6	310.9	2460	1085	919.8	504.2	489.3	2460	730.4	722.7	234.7	310.9	1118
Iron (mg)	11.94	10.54	4.511	2.29	23.1	13.21	11.12	4.656	5.69	23.1	9.832	9.995	3.484	2.29	16.08
Fruit (serves)	1.344	1.12	1.041	0	3.46	1.519	1.21	1.018	0	3.43	1.052	0.775	1.055	0	3.46
Vegetable (serves)	1.473	1.32	1.355	0	5.51	1.644	1.505	1.140	0	4.85	1.189	0.365	1.670	0	5.51
Total F/V (serves)	2.817	2.5	1.767	0.3	7.8	3.163	3.505	1.738	0.73	7.8	2.241	2.225	1.733	0.3	6.64

Table 6 Weekday and Weekend Weighed Food Diary Intake

Nutrient Intake	Total Weekday and Weekend Weighed					Boys					Girls				
	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD	Min	Max
Energy (kJ)	8964	8853	2390	3838	13748	9585	9286	2298	5334	13748	7928	8208	2213	3838	11488
Carbohydrate (g)	250.2	246.9	69.11	88.43	412.7	261.4	262.7	68.04	151.9	412.7	231.4	226.6	68.15	88.43	346.9
Protein (g)	82.98	79.06	34.55	24.99	214.8	92.02	80.46	35.47	36.72	214.8	67.90	59.87	27.52	24.99	123.1
Total fat (g)	84.91	81.45	28.40	29.44	158.0	91.91	88.33	28.64	44.62	158.0	73.26	73.20	24.31	29.44	117.4
Saturated fat (g)	34.45	31.97	12.69	11.99	68.84	37.41	35.17	12.76	17.32	68.84	29.53	29.04	11.17	11.99	54.16
Dietary fibre (g)	25.49	22.92	10.17	5.57	62.06	28.00	25.35	10.51	11.21	62.06	21.31	20.29	8.174	5.57	40.18
Carotenoids (µg)	2500	1306	2747	186.1	14199	2816	2013	2983	191.5	14199	1974	842.8	2263	186.1	8035
Sodium (mg)	2857	2622	1112	1006	6107	3086	2852	1129	1682	6107	2477	2347	990.9	1006	5010
Calcium (mg)	1019	885.3	494.1	114.7	2564	1121	935.7	532.5	489.3	2564	849.1	803.7	373.9	114.7	1923
Iron (mg)	12.48	11.54	4.736	2.29	24.94	13.44	12.37	4.518	5.69	23.13	10.89	10.19	4.754	2.29	24.94
Fruit (serves)	1.255	0.99	1.098	0	4.98	1.433	1.135	1.175	0	4.98	0.96	0.66	0.901	0	3.46
Vegetable (serves)	1.872	1.44	1.659	0	8.76	1.991	1.625	1.657	0	8.76	1.675	1.16	1.679	0	5.51
Total F/V (serves)	3.128	2.76	2.106	0.3	11.23	3.424	3.255	2.161	0.38	11.23	2.635	2.225	1.955	0.3	8.2

