An investigation of the fruit and vegetable intake of Pacific and NZE women with different body composition profiles

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Abstract

Background: Obesity is a significant health issue in New Zealand and is closely related with diet. Fruit and vegetables play numerous roles in the aetiology and physiology of obesity. Little is known about current fruit and vegetable consumption in Pacific and NZE women.

Aim: To conduct an in-depth investigation of the fruit and vegetable intake (quantity, quality and habits) of NZE and Pacific women participating in the PROMISE study to determine links with body composition outcomes.

Methods: Cross-sectional study analysing fruit and vegetable intake and body composition in 161 NZE and 142 Pacific women living in Auckland, New Zealand. Women completed a 5-day food record (5d-FR) and 7-day Dietary Diversity Questionnaire (DDQ) from which fruit and vegetables were isolated. Anthropometrics and Dual X-Ray Absorptiometry (DEXA) were used to assess body composition. Correlations of fruit and vegetable intake and body composition were made using Spearmans rho. Multiple linear regression was used to analyse predictors of body composition.

Results: Combined daily servings and vegetable servings were significantly inversely correlated with BMI (-0.15, -0.16) and BF% (-0.21, -0.20); specifically, green (-0.14, -0.18) and yellow Vitamin-A-rich (-0.12, -0.14) and cruciferous (-0.13, -0.18) vegetables when adjusted for age and ethnicity. Every one serve (75g) of vegetables significantly predicted a reduction of 0.65kg/m^2 in BMI and 1.16% in BF% for women combined. The majority of women did not meet fruit or vegetable guidelines regardless of ethnicity, BMI or BF%. NZE consumed significantly more yellow vitamin-A-rich and cruciferous vegetables than Pacific, who consumed more starchy vegetables. Pacific women consumed the highest servings later in the day (Lunch, Afternoon tea, Dinner) than NZE (Breakfast, Lunch, Dinner). All women consumed the highest servings at dinner. Most commonly consumed vegetables were carrots, onions, lettuce, tomatoes and potato. Pacific women had higher carbohydrate and lower fibre intake from fruit and vegetables than NZE in the obese BMI category.

Conclusions: Daily serves of fruit and vegetables were significantly correlated with body composition although overall current intake is low. Pacific and NZE women have significant differences in fruit and vegetable intake and consumption patterns and corresponding nutrient levels.

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List of Abbreviations:

ADP: Air Displacement Plethysmography

ATP: Adenosine Triphosphate

BF%: Body Fat Percentage

BIA: Bioelectrical Impedance Analysis

BMI: Body Mass Index

CHD: Coronary Heart Disease

CVD: Cardiovascular Disease

WC: Waist Circumference

WHO: World Health Organization

DDQ: Dietary Diversity Questionnaire

DEXA: Dual-energy X-ray Absorptiometry

FFA: Free Fatty Acids

GIP: Gastric Inhibitory Peptide

GLP-1: Glucagon-Like Peptide One

GLUT-4: Glucose Transporter Four

IHD: Ischaemic Heart Disease

IL-6: Interleukin Six

MOH: Ministry of Health

NPY: Neuropeptide Y

NZE: New Zealand European

NZ: New Zealand

OECD: Organization for Economic Co-operation and Development

POMC/CART: Pro-opiomelanocortin and cocaine and amphetamine-related transcript

PYY: Peptide YY

ROS: Reactive Oxygen Species

SCFA: Short Chain Fatty Acids

TCA: Tricarboxylic Acid

TH1: T-Helper-one

TNFα: Tumour Necrosis Factor

T2DM: Type Two Diabetes Mellitus

WCRF: World Cancer Research Fund

WHR: Waist-to-Hip Ratio

WHtR: Waist-to-Height Ratio

5d-FR: Five-day Food Record

Chapter 1: Introduction

Background

Obesity is a growing global issue affecting one third of adults worldwide. The World Health Organisation (WHO) defines obesity as "an abnormal or excessive fat accumulation that may impair health", meaning the level of fat in the body negatively effects the overall functioning of the body (World Health Organization, 2020b).

Fat, or adipose tissue, plays a number of important roles in the body, including in metabolism, mediation of inflammation and the endocrine regulation of long term and short energy balance (Codoner-Franch and Alonso-Iglesias, 2015). An increase in the number and size of adipocytes (fat cells) results in excess hormone and adipokine production from adipocytes, which in turn stimulates activation of inflammatory immune cells, leading to localised and chronic inflammation (Singla et al., 2010). Chronic inflammation impairs normal metabolic homeostasis such as glucose and lipid metabolism and is therefore thought to be an underlying cause of CVD, T2DM, and some cancers (Singla et al., 2010). Therefore, excess body fat (obesity) is a risk factor for poor metabolic health and subsequent risk of chronic disease (Chan and Woo, 2010)

Obesity is defined as a Body Mass Index (BMI) of $\geq 30kg/m^2$ (World Health Organization, 2020b) and associated with a high Body Fat Percentage (BF%) of total weight (Romero-Corral et al., 2008). The Organisation for Economic Co-operation and Development (OECD), ranks New Zealand (NZ) as having the third highest rates of obesity (OECD, 2019). The most recent National Health Survey in NZ, reports that one in three adults are obese; around 1.22 million people (Ministry of Health, 2015a). Additionally, 34.3% of NZ adults are classified as overweight, and only 33.4% of adults with a BMI in a normal range.

Demographic disparities of obesity rates are evident in NZ. While only 33% of New Zealand European (NZE) adults are obese, 67% of Pacific in NZ are obese (Ministry of Health, 2020a). Difference in disease prevalence between ethnicities also exist.. One in four adults are at very high risk of obesity-associated morbidity (Ministry of Health, 2015a).

Table 1.1: Obesity and disease rates between ethnicities in adults

	NZE	**Pacific**
Obesity	33%	67%
Type 2 Diabetes	4.9%	14.6%
Ischaemic Heart Disease	4.6%	2.7%
Stroke	1.8%	1.0%
Hypertension	17%	13.4%

Estimation of total population statistics based on New Zealand Health Survey; NZE=7,406, Pacific=613 adults *(Ministry of Health, 2020a)*.

The aetiology of obesity is dictated by a combination of diet, genetics, physical activity, and age (Baqai and Wilding, 2014). It occurs due to a caloric mismatch leading to positive energy balance; when an individual's caloric intake exceeds their caloric output (Singla et al., 2010). The current western environment is thought to be supportive of this positive energy balance and of obesity through sedentary lifestyles and the availability of cheap, energy-dense, nutrient-poor foods (Baqai and Wilding, 2014), usually accompanied by a low proportion of nutrient-dense foods (Codoner-Franch and Alonso-Iglesias, 2015). A combination of food quantity (i.e. portion sizes) and food types in an individual's diet (i.e. food choices) contributes to a positive energy balance (Baqai and Wilding, 2014).

While the body has mechanisms in place to maintain body weight through diet, such as hunger and satiety hormones (ghrelin and leptin), these can easily be overridden by overeating (Baqai and Wilding, 2014). Overeating can occur by consuming large portion sizes, irregular eating patterns, and eating foods that produce a poor satiety response. Foods high in fat and sugar are weak stimulators of satiety, while foods high in complex carbohydrates and fibre produce strong satiety signals, thus making an individual feel satiated with a lower calorie intake (Baqai and Wilding, 2014). For this reason, the current health messages are to reduce highly processed salty and sugary foods (as they delay satiety), and to increase fruit and vegetables contributing to satiety in the diet (Tohill, 2005).

Dietary patterns, including patterns of fruit and vegetable consumption, are connected to obesity and risk of obesity-associated diseases. Dietary patterns include the quantity, type, diversity, distribution and preparation of fruit and vegetables (Wilunda et al., 2020). The replacement of energy-dense, high saturated fat, high free sugar and salt foods with Fruit and vegetables, which are naturally low in energy, saturated fat, free sugars and salt, and high in fibre, may reduce overall energy intake. Thus, energy expenditure required to create energy balance is reduced, ultimately leading to reduced risk of obesity and obesity-associated diseases (Aune et al., 2017, Wilunda et al., 2020). Increasing fruits and vegetables with a meal can lead to reduced intake of other foods, however eating large portions of fruit and vegetables between or after meals in addition to energy-dense foods may instead add additional calories (Wilunda et al., 2020). Therefore, the distribution of fruit and vegetables throughout the day can be key in weight management.

The type of fruit or vegetable consumed is important due to differences in macronutrient, micronutrient and fibre compositions. Some fruit and vegetables have a higher energy and carbohydrate content, and different preparation practices may add further energy to their consumption e.g. frying in oil versus boiling (Houchins et al., 2013, Lako and Nguyen, 2001, Nour et al., 2018). Therefore, higher intakes of these vegetables by some individuals may contribute to differences in their body composition (Nour et al., 2018).

Fibre is an important component of fruits and vegetables responsible for regulation of energy intake, absorption, appetite and satiety cues, and the gut microbiome. The structure of dietary fibre traps nutrients allowing for reduced and sustained release of nutrients ultimately reducing energy intake and prolonging satiety (Howarth et al., 2001, Widianingrum et al., 2020). Soluble fibres form a gel that increases gastric distention and slows gastric emptying while insoluble fibre works similarly by increasing bulk (Howarth et al., 2001, Widianingrum et al., 2020). Consuming fibres from a range of fruit and vegetables has been shown to enhance the diversity of the gut microbiome and promote the growth of colonies that produce anti-carcinogenic and anti-obesogenic short-chain fatty acids (SCFA) such as butyrate (Cui et al., 2019). Therefore, a diet low in fruit and vegetables could promote weight gain even if energy balance is met (Davis, 2018) while a diet rich in fruits and vegetables can help prevent against excess energy intake and weight gain (Dreher and Ford, 2020).

Fruit and vegetables provide micronutrients, anti-oxidants and phytochemicals that collectively help to improve metabolic health by reducing inflammation, preventing DNA and endothelial damage, reducing platelet aggregation, supporting the immune system, maintaining a healthy gut microbiota and reducing plasma cholesterol concentrations which are well known contributors to these diseases (Aune et al., 2017, McKay et al., 2020). In contrast, a diet low in fruits and vegetables is associated with a pro-oxidant and a pro-inflammatory state due to the inhibition of many of these mechanisms. A systematic review by Aune et al. (2017) compared a range of prospective cohort studies and found significant association between a fruit and vegetable intake of 500-800g/day and reduced risk of CVD, CHD, T2DM, cancer, and obesity.

Micronutrient deficiencies can promote obesity as many are intricately involved in metabolic pathways including energy storage and utilization pathways (Thomas-Valdes et al, 2016). Vitamin A deficiency is known to be common in those with obesity. Retinoic acid regulates adipogenesis and deficiency leads to growth of adipose tissue and proinflammatory cytokines such as leptin. Leptin is an appetite stimulant which further promotes weight gain (Garcia, 2012) and promotes a chronic inflammatory state associated with obesity-related diseases (Garcia, 2012). Other components of fruit and vegetables such as polyphenols are thought to play roles in the regulation of adipocyte growth and apoptosis (Wilunda et al., 2020). On the other hand, obesity can promote deficiencies and there is an association between obesity and vitamin and mineral deficiencies (McKay et al., 2020). This is related to increased storage of fat-soluble vitamins in obesity, impaired absorption secondary to obesity-associated intestinal inflammation, and poor nutrient intake in the diet (McKay et al., 2020). It is theorized that a nutrient-poor diet may result in excess energy intake as the body signals to continue to eat until micronutrient needs are met (McKay et al., 2020). Because fruit and vegetables vary in their nutritional composition, a low diversity of fruit and vegetables can lead to poor intake of some micronutrients despite large portion sizes. Therefore, inadequate quantity and diversity of fruit and vegetable intake can be obesogenic.

Different cultures have different eating patterns, habits, preferences and practices. New Zealand is a multicultural society and NZE and Pacific people's intake of fruit and vegetables differ in portion and in preference (Mackay et al., 2018). Ferguson et al. (1995) showed that Pacific were likely to eat less cauliflower, broccoli, carrots, and tomatoes but more onion, green banana, and taro than NZE adults, highlighting food choices, and subsequent diversity, is associated with cultural habits.

Justification for Research

It is estimated that obesity is one of the top three risk factors of shortened life span in NZ and should therefore obtain significant attention from a public health perspective (Ministry of Health, 2020a).

The WHO recommends a minimum of 400g of non-starchy fruits and vegetables for the prevention of non-communicable diseases such as some cancers, T2DM and CVD (Tohill, 2005). In NZ, the Ministry of Health (MOH) previously recommended at least three 80g portions of vegetables and two 80g portions of fruit per day; equivalent to around 400g/day (Ministry of Health, 2015b). New guidelines released in December 2020, increased this to five 75g servings of vegetables and two 150g servings of fruit; the equivalent of 675g/day (Ministry of Health, 2020b). The MOH also recommends a minimum of 25g of dietary fibre daily in line with the suggested dietary target (Ministry of Health, 2015b, National Health and Medical Research Council, 2006). For heart health, the Heart Foundation recommends three to four serves each of fruit and vegetables (Heart Foundation, 2018). Despite the significant health benefits of consuming fruit and vegetables, the recent National Health Survey identified that only 32.5% of New Zealanders are meeting the previous recommended guidelines (Ministry of Health, 2020a).

There is currently a lack of understanding of specific fruit and vegetable habits of obese and normal BMI Pacific and NZE women. The health survey fails to grasp the connection between body composition, ethnicity and fruit and vegetable dietary patterns of New Zealanders. Dietary patterns include the quantity, diversity, distribution and preparation of fruit and vegetables. There is need to investigate the potential correlation of fruit and vegetable habits including quantity, diversity, distribution patterns, and preparation habits with body composition outcome.

Study Aim

To conduct an in-depth investigation of the fruit and vegetable intake (quantity, quality and habits) of NZE and Pacific women participating in the PROMISE study to determine links with body composition outcomes.

Objectives

1. To analyse and compare types of fruit and vegetables and their nutritional contribution to dietary intake – quantity and quality (single items versus combined dishes) – of Pacific and NZE women with different body composition profiles.
2. To analyse and compare the distribution throughout the day of fruit and vegetable intakes (eating habits) of Pacific and NZE women with different body composition profiles.
3. To analyse and compare the diversity and preferences of fruit and vegetable intakes of Pacific and NZE women with different body composition profiles.

Structure of the thesis

Chapter 1 is an introduction including aims and objectives. Chapter 2 is a literature review of current evidence and gaps related to fruit and vegetable intake in obese and non-obese Pacific and NZE women. Chapter 3 is the research manuscript. Chapter 4 is a summary of research, strengths and limitations, and future recommendations.

Contributions of researchers

Researcher	Contribution
Amy Richter	Primary author of this thesis including data and statistical analysis, interpretation and development of final manuscript.
A/Prof. Rozanne Kruger Academic supervisor	Co-investigator of the PROMISE study. Concept and research design of the PROMISE study and ethics approval. Main supervisor of thesis including interpretation of results, reviewing and approval of thesis.
Prof Bernhard Breier	Lead investigator of the PROMISE study. Concept and research design of the PROMISE study, ethics application.
Jo Dawson, Nikki Renall, Carlien van der Merwe	Dietitians responsible for dietary data collection and review interviews, checking of food records, data processing of the PROMISE study
Jo Dawson, Nikki Renall, Sophie Kindleysides, Niamh Brennan, Moana Manukia, Sherina Holland, Owen Mugridge, Elizabeth Cullen, Bronte Anscombe, Laura Mickleson, Ashleigh Jackson, Shivon Singh, Amelia Franklin, Alexandra Thompson, Anishka Ram, Sunna Jacobsen	Participant screening, recruitment and execution of data collection as part of the PROMISE study. Data entry and processing.

Chapter 2: Literature Review

Definition of Obesity

Obesity is defined as

"abnormal or excessive fat accumulation that may impair health".

World Health Organization (2020b)

Obesity occurs when the amount of adipose tissue in the body has increased to such an extent that it negatively affects the overall function of the body. Meaning, it causes abnormal physiological shifts at a cellular and systemic level leading to altered production of cells, cell signalling, and cellular function. Increased adiposity affects all organ systems including the coronary, respiratory, gastrointestinal, integumentary and endocrine systems, and results in increased risk of non-communicable diseases. (Bellows et al., 2011, Bednarska-Makaruk et al., 2017, Sikaris, 2004)

Body Mass Index (BMI) is measure of a persons' weight divided by their height squared and is used as a screen of nutritional status (World Health Organization, 2020b). Based on BMI, individuals can be categorized as follows:

Table 2.1: BMI definition of obesity

BMI (kg/m^2)	Nutrition Status
<18.5	Underweight
18.5 – 24.9	Normal weight
25.0 – 29.9	Overweight
30.0 – 34.9	Obesity Class 1
35.0 – 39.9	Obesity Class 2
>40	Obesity Class 3

An increased BMI is associated with increased Body Fat percentage (BF%) (Zierle-Ghosh and Jan, 2020). However, BMI has poor sensitivity as a predictor of BF% as BMI does not discriminate between lean and fat mass (Oliveros et al., 2014). Body fat percentage (BF%) is the percentage of total body weight that is adipose tissue and can be determined through a Bioelectrical Impedance Analysis (BIA), Dual-energy X-ray Absorptiometry (DEXA), ultrasound (Shuster et al., 2012) or air displacement plethysmography (ADP) (Fields et al., 2002). There are currently no official guidelines as to the BF% cut-off that determines obesity, however a BF% of ≥35% has been used to classify excess adipose tissue in women and is associated with the same risk of metabolic disease as BMI-defined obesity (Oliveros et al., 2014, Schrivers et al., 2016). It has been argued the relationship between BMI and BF% is different for the NZE and Pacific population, therefore BMI may inaccurately classify more Pacific with a normal BF% as obese and exclude NZE with a high BF% (if BMI normal) (Rush et al., 2004, Oliveros et al., 2014). Other evidence suggests these differences lack the significance to justify alterations of BMI cut-offs as it may result in missing individuals who are at risk of metabolic disease (Taylor et al., 2010). Therefore, the use of both measurements is useful in the analysis of obesity and metabolic disease risk.

Body fat, or adipose tissue, can be separated into two categories. Subcutaneous adipose tissue lies below the skin while visceral adipose tissue lines internal organs (Shuster et al., 2012, Mittal, 2019). Central adiposity is an indicator of visceral adiposity and is measured through waist circumference (WC) and waist-to-hip ratio (WHR). For women, the WC guideline is <80 cm (Ministry of Health, 2015c) and WHR is <0.85 (World Health Organization, 2008). When compared to subcutaneous fat, visceral adiposity has increased lipolysis and inflammatory immune cells and has been associated with impaired metabolic homeostasis such as impaired glucose and insulin regulation, altered plasma lipids and low grade inflammation (Gub et al., 2009, Singla et al., 2010, Codoner-Franch and Alonso-Iglesias, 2015, Shuster et al., 2012).

Prevalence of Obesity

Obesity is a globally increasing health issue. Currently, over a third (39%) of adults across the globe are classified as overweight and 13% of Adults are classified as obese according to the World Health Organisation (World Health Organization, 2020b). This is concurrent with an average of 8.4% of healthcare budgets in the OECD being spent on obesity-related diseases (OECD, 2019). New Zealand is ranked third highest in the OECD for prevalence of obesity as 65.1% of the population over 15 years old are classified as overweight or obese (World Health Organization, 2020b, OECD, 2017). The most recent health survey showed 66.2% (2.65 million) of New Zealanders, were classified as overweight and obese, a third (30.9%); 1.22 million) were obese, and the remainder (35.3%) were classified as overweight (Ministry of Health, 2020a).

There are disparities in the prevalence of obesity in NZ. The latest statistics show 33% of NZE are obese while 67% of Pacific adults in NZ are classified as obese (Ministry of Health, 2020a). Adults from Pacific decent are 2.5 times more likely to be obese compared to those who are not (Ministry of Health, 2015c). In NZ, women are more likely than men to have a higher waist circumference; an indicator of visceral adiposity (Ministry of Health, 2015c).

One in four adults in NZ are at very high risk of obesity-related morbidity (Ministry of Health, 2015c). From 2011 to 2013, 55% of Pacific adults were at very high risk of obesity-related diseases compared to 24% of NZE adults (Ministry of Health, 2015c). The latest statistics show Pacific women over the age of 15 are 1.54 times more likely to have ischaemic heart disease (IHD), 2.60 times more likely to develop heart failure, 1.54 times more likely to have high cholesterol, 1.48 times more likely to have hypertension, and 3.25 times more likely to develop T2DM when compared to non-pacific New Zealanders. Pacific have higher rates of T2DM than NZE (14.6% versus 4.6%, respectively) while NZE have higher rates of IHD (NZE=4.6%

versus Pacific=2.7%), HTN (NZE=17% versus Pacific=13.4%) and strokes (NZE=1.8% versus Pacific=1.0%) (Ministry of Health, 2020a).

It has been estimated that obesity is one of the top three risk factors of shortened life span in NZ and therefore should require significant attention from a public health perspective (Ministry of Health, 2015c). Reducing the prevalence of obesity could play a significant role in reducing the disease burden on health care systems (OECD, 2019).

Aetiology and pathophysiology of obesity

Adipose tissue is the primary energy store of the body (Mittal, 2019). Adipose tissue grows firstly through adipose cell hyperplasia, then hypertrophy, in response to excess energy intake to facilitate increased energy storage (Codoner-Franch and Alonso-Iglesias, 2015). Long term this results in obesity (Kindleysides et al, 2019).

Energy is stored as triacylglycerides, which can be broken down via lipolysis to generate free fatty acids and glycerol. These feed into the TCA (tricarboxylic acid) cycle and the electron transport chain to provide usable energy (ATP) which is essential between eating periods (Thomas-Valdes et al, 2016). In obesity, lipolytic activity of adipocytes increases leading to increased circulating free fatty acids (FFA) and glycerol; also known as dyslipidaemia (Singla et al., 2010). Free fatty acids are involved in the generation of reactive oxygen species (ROS) and cytokines which promote inflammation and impair vasodilation. High circulating FFA promote atherosclerotic plaque formation (Ryden, 2015), narrowed blood vessels and endothelial dysfunction leading to risks of hypertension, atherosclerosis, coronary heart disease (CHD) and stroke (Singla et al., 2010). Excessive circulating FFA further impairs the movement of insulin-sensitive glucose transporter 4 (Glut 4) to the cell surface resulting in impaired glucose uptake and increased glucose production (Singla et al., 2010) therefore increasing risk of T2DM.

Importantly, adipose tissue is involved in metabolism such as regulating glucose and lipid homeostasis, inflammatory signalling, and regulating hunger and satiety pathways (Codoner-Franch and Alonso-Iglesias, 2015, Singla et al., 2010). Adipocytes release hormones and signalling molecules such as leptin, adiponectin, oestrogen, resistin and cytokines such as interleukin-6 (IL-6), and Tumour Necrosis Factor (TNFα) from the macrophages which participate in the regulation of these metabolic pathways (Singla et al., 2010). Leptin is an anorexigenic adipokine that ordinarily heightens satiety signals to demote energy intake in response to increased energy storage. (Hemling and Belkin, 2011). The concentration of these signalling molecules increase or decrease in relation to the size and number of the adipocytes, resulting in altered metabolic regulation in obesity (Kershaw and Flier, 2004).

Obesity has many modifiable risk factors(Sharma et al., 2016, Davis, 2018). It can occur as a result of a combination of multiple factors such as diet, physical activity, age and genetics (Baqai and Wilding, 2014, Cruz-Requena et al, 2016). The modern-day western lifestyle and environment is thought to be a contributor to positive energy balance and obesity through highly sedentary lifestyles and a high prevalence of easily accessible, cheap, energy-dense, nutrient-poor foods (Baqai and Wilding, 2014). Diet and physical activity can be manipulated by the individual to achieve energy balance for weight maintenance or deficit for weight loss (Mytton et al., 2014).

Energy balance is partially controlled by communication between the gut and the arcuate nucleus in the hypothalamus. The absence or presence of food moving through the gastrointestinal tract provides feedback that promotes the initiation and inhibition of feeding (Amin and Mercer, 2016). When food is eaten, multiple signals act on the arcuate nucleus in the hypothalamus to supress the release of Neuropeptide Y (NPY) which stimulates hunger and to increase the expression of pro-opiomelanocortin and cocaine and amphetamine-related transcript (POMC/CART) which supresses hunger (Baqai and Wilding, 2014, Singla et al., 2010).

After eating, the stomach stretching stimulates the vagal nerve which feedbacks to the arcuate nucleus to reduce appetite. Rising blood glucose and amino acids as a result of nutrient absorption, along with the subsequent increase in hormones such as leptin and insulin, also act to decrease NPY and increase POMC/CART (Baqai and Wilding, 2014). The hormones glucagon like peptide -1 (GLP-1), gastric inhibitory peptide (GIP) and Peptide YY (PYY) are released from eneteroendocrine cells in response to nutrients in the intestinal tract (McCarty et al., 2020); also known as the ileal brake (Howarth et al., 2001). The result is reduced gastric emptying and increased sense of satiety. GLP-1 has been shown to promote weight loss through slowing gastric emptying when given exogenously (Howarth et al., 2001). These signals regulate satiety to finish a meal and satiation between eating periods.

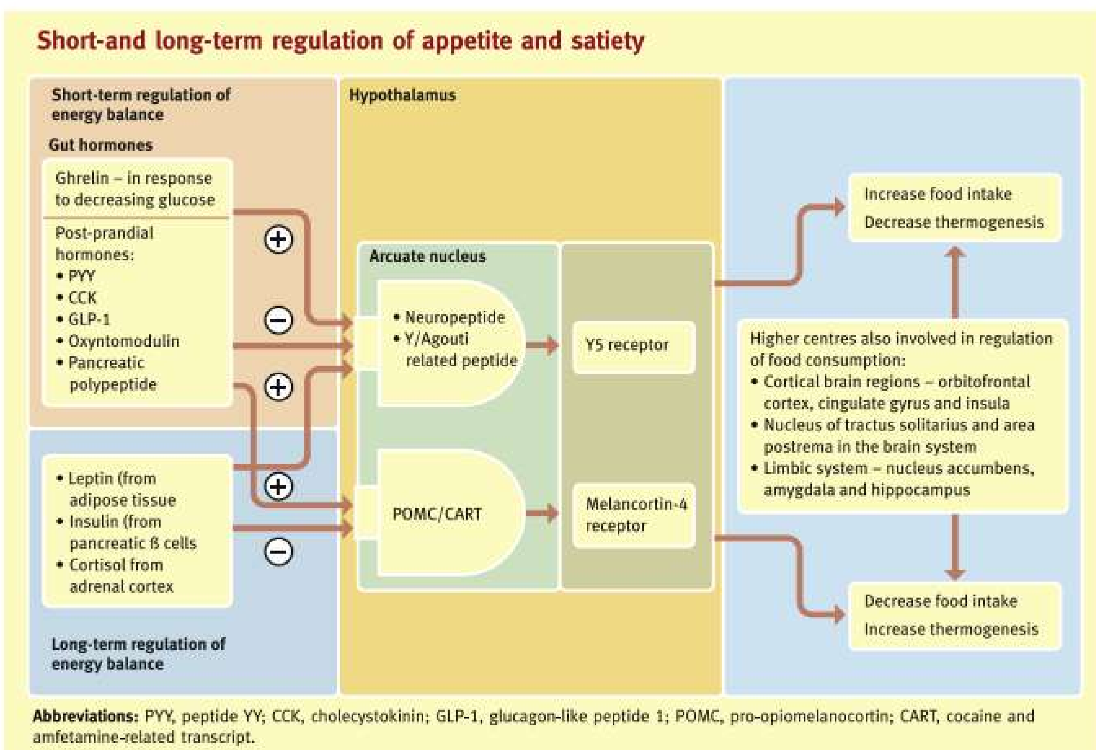

Figure 2.1: Neurological regulation of food intake (Baqai and Wilding, 2014)

These hormonal and nervous signals can be overridden if a food or eating environment is pleasurable and an individual wants to keep eating (Baqai and Wilding, 2014). They can be stimulated with high sugar and high fat foods which stimulate an increased dopamine response. Large portion sizes and irregular eating patterns contribute to excess energy intake. It can also be manipulated by the types of food eaten as some foods trigger a weaker or stronger satiety response than others. Foods high in fat and sugar are high in energy and are weak stimulators of satiety (Baqai and Wilding, 2014). This makes it easier to eat more energy than needed. In contrast, foods high in complex carbohydrates and fibre, such as fruit, vegetables, wholegrains and legumes (Howarth et al., 2001) produce stronger satiety signals, thus making an individual feel satiated for longer and with a lower energy intake. This reduces energy intake within the meal and delays onset of the next period of energy intake (Cui et al., 2019). Therefore, a combination of the quantity and quality of an individuals' diet contribute to their risk of positive energy balance and obesity.

Fruit and Vegetables

Replacing high saturated fat, high sugar, and high salt foods with fruit and vegetables may help to reduce the risk of obesity due to an overall lower calorie intake (Cruz-Requena et al, 2016). Studies analysing the globally changing diet patterns, have shown increased intakes of foods high in saturated fats and sugars are associated with obesity and poor metabolic health (Jayasinge et al., 2019, Schrivers et al., 2016, Gutierrez-Pliego et al., 2016, Alae-Carew et al., 2019, Xu et al., 2016, Quatromani et al., 2002, Schulze et al., 2012). High saturated fats and energy-dense food contribute to increased blood cholesterol and triglyceride levels, and further promotes storage of energy. High free sugar intake raises blood sugar quickly and increases risk of insulin resistance and diabetes. High salt diets can lead to higher water absorption and higher blood pressure (Wilson et al, 2020). Fruit and vegetables are naturally low in energy, saturated fat, free sugars, and salt, thereby reducing risk of metabolic disease as intake increases (Aune et al., 2017). Fruit and vegetables are high in fibre, micronutrients, phytochemicals and anti-oxidants which are crucial in lowering overall energy intake, reducing blood cholesterol, improving gut microbiota composition, reducing oxidative stress, and aiding the immune system (Aune et al., 2017, Wilson et al, 2020, Wallace et al., 2019) .

Studies have shown mixed results concerning the impact of fruit and vegetables on body weight (Table 2.2). One prospective cohort study found a 21g weight decrease for every 100g of vegetables consumed, and in contrast, a 75g increase for every 100g of fruit consumed (Yuan et al., 2018). A cross sectional study by Yu et al. (2018) found every 1.5 half cup serving of vegetables was associated with a decrease in BMI (0.05kg/m^2) and BF% (0.18%). However, for every 1.3 half cup serving of fruit there was a 0.09kg/m^2 decrease in BMI and 0.31% decrease in BF%.

Table 2.2: Fruit and vegetable intake and weight change.

Study	Country	Aim	Methods	Relationship between body composition and fruit and vegetable intake
Prospective Cohort				
(Bertoia et al., 2015)	U.S.A Pooled from three cohorts: • Nurses' Health Study: 35,408 female nurses aged 30-55y • The Health Professionals Follow-up Study: 17,996 male health professionals aged 40-75y • Nurses' Health Study 2: 64,514 female nurses aged 25-42y	To investigate the relationship between fruit and vegetable intake and weight change	• Dietary intake measured through validated FFQ including serving size i.e. ½ cup of vegetable or one fruit. • Measured at beginning and end of a 4-y interval. • Self-reported weight and height. • Correlations based on pooled mean weight loss • Linear regression adjusted for age, BMI, smoking status, physical activity, hours watching TV, hours of sleep, fried potatoes, juice, whole grains, refined grains, fried foods, nuts, whole-fat dairy, low-fat dairy, sugar-sweetened beverages, sweets, processed meats, non-processed meats, trans fat, alcohol and seafood.	Each ½ cup increase in vegetables was associated with weight change over 4y: • 0.11kg loss • 0.05kg loss for a BMI $<25kg/m^2$ • 0.18kg loss for a BMI $\geq25kg/m^2$ and $<30kg/m^2$ • 0.31kg loss for a BMI $\geq30kg/m^2$ Each one fruit increase associated with weight change over 4y: • 0.24kg loss • 0.15kg loss for a BMI $<25kg/m^2$ • 0.31kg loss for a BMI $\geq25kg/m^2$ and $<30kg/m^2$ • 0.36kg loss for a BMI $\geq30kg/m^2$
(Mozaffarian et al., 2011)	U.S.A Pooled from three cohorts: • Nurses' Health Study: 50,422 female nurses aged 30-55y • The Health Professionals Follow-up Study: 22,557 male health	To investigate the relationship between multiple lifestyle changes and weight gain	• Dietary intake measured through validated FFQ including serving size i.e. ½ cup of vegetable or one fruit. • Measured at beginning and end of a 4-y interval. • Self-reported weight and height. • Correlations based on pooled mean weight loss • Adjusted for age, BMI, sleep duration, smoking status, physical activity, television watching, alcohol.	Every one increase in vegetable servings/day associated with 0.1kg weight loss Every one increase in fruit servings/day associated with 0.22kg weight loss Every one increase in potato servings/day associated with 0.58kg weight gain

Study	Country	Aim	Methods	Relationship between body composition and fruit and vegetable intake
	professionals aged 40-75y • Nurses' Health Study 2: 47,898 female nurses aged 25-42y			
(Yuan et al., 2018)	China • 4357 men and women. • Aged 18-65	To examine the relationship of fruit and vegetable intake and body composition change	• Height and weight measured by trained professionals at a five-year interval. • Fruit and vegetable consumption analysed by three day 24-hour dietary recall including one weekend day. • Linear regression adjusting for Age, BMI, area, education, energy intake, physical activity, smoking status, alcohol, and sugar-sweetened beverages. Based on average BMI of • 23.1kg/m^2 in men • 23.3kg/m^2 in women	Every 100g increase of fruit and vegetable consumption was associated with: • 211g weight loss and a decrease in BMI by 0.94kg/m^2 in men • 140g weight loss and a decrease in BMI of 0.29kg/m^2 in women
(Wilunda et al., 2020)	Japan • 54,015 men and women • Aged 40-69y	To investigate fruit and vegetable intake and weight change	• Five-year follow up • Self-reported weight measurements • Validated FFQ with varying serving sizes • Adjusted for gender, BMI, physical activity, area, alcohol, cereals, processed meat, unprocessed meat, fish, confectionaries, potato, soy foods, cola, nuts	• Body weight decreased by 21g for every 100g increase in vegetables consumed • Body weight increased 75g for every 100g fruit consumed • Body weight increase 6g for every 100g fruit or vegetable consumed
Cross-Sectional				
(Yu et al., 2018)	Canada • 26,340 men and women • Aged 35-69	To assess fruit and vegetable intake, including juices, on body composition	• Body composition measured by bioelectrical impedance • One serving vegetables equivalent to ½ a cup or 125ml of fresh, frozen, canned or cooked.	Average intake • 2.1 (1.4) vegetable serves/day in men and 2.7 (1.5) in women • 1.8 (1.4) fruit serves/day in men and 2.3 (1.3) in women • 4.9 (2.7) total serves/day in men and 5.6 (2.6) in women

Study	Country	Aim	Methods	Relationship between body composition and fruit and vegetable intake
			• One fruit serving equivalents to ½ cup or 125ml fresh, frozen, canned fruit • One serving equivalent to ½ cup or 125ml 100% fruit or vegetable juice • Adjusted for age, sex, area, ethnicity, education, marital status, smoking status, alcohol, physical activity, chronic disease	Average body composition: • BMI: 28.7kg/m^2 (5.6) in men, 28.4kg/m^2 (6.3) in women • WC: 97.0 cm (14.0) in men, 92.7 cm (6.3) in women • BF%: 30.8% (9.4) in men, 34.7% (8.8) in women • Fat mass: 9.1kg (4.3) in men, 10.1kg (4.4) in women Every one SD increase in fruit and vegetable associated with • 0.12kg/m^2 reduction in BMI • 0.40 cm reduction in WC • 0.30% reduction in BF% • 0.14kg reduction in fat mass Every one SD increase in vegetable associated with • 0.05kg/m^2 reduction in BMI • 0.13cm reduction in WC • 0.18% reduction in BF% • 0.08kg reduction in fat mass Every one SD increase in fruit associated with • 0.09kg/m^2 reduction in BMI • 0.36 cm reduction in WC • 0.31% reduction in BF% • 0.14kg reduction in fat mass
(Bes-Rastrollo et al., 2006)	Spain • 5094 men and 6613 women	To investigate fibre intake and associated with weight gain over five years.	Validated FFQ with portion sizes varied based on food composition table for Spain. Separated by quintiles of fibre intake: Men: • <18g • 18-23g • 23-27g • 27-33g • >33g Women • <20g • 20-24g • 24-28g	Inverse association shown by OR between increasing total fruit and vegetable consumption and >3kg weight gain in five years, but only among men only Quintiles: 1- Reference 2- 0.78 3- 0.89 4- 0.70 5- 0.54

Study	Country	Aim	Methods	Relationship between body composition and fruit and vegetable intake
			• 28-35g • >35g Adjusted for energy intake	
Longitudinal				
(Aljadani et al., 2019)	Australia • 4083 women • Aged 21-31	To investigate the relationship between diet and six year weight change	Women of a healthy BMI (>18.5kg/m^2 - <25kg/m^2). Weight taken at beginning and end of six years. Dietary data taken through validated FFQ Australian Recommended Food Score (ARFS): A score in which points are given for regular consumption of foods on the FFQ that align with the National Dietary Guidelines The Fruit and Vegetable Index (FAVI): A scale from the FFQ in which points are given for fruit and vegetables with 'never' scored zero ad '≥3 times per day' scored nine. Linear regression adjusted for physical activity, education, number of births, area, marital status, smoking, energy intake, and baseline weight	Every one point increase in fruit and vegetable index score (FAVI) associated with 12g less weight gain over 6 years. Every one-point increase in Australian Recommended Food Score (ARFS) associated with 33g less weight gain over 6 years.
(Mirmiran et al., 2012)	Iran • 1938 men and women • Aged 19-70	To analyse the effects of intake of phytochemical-rich foods on body composition	Adjusted for sex, age, BMI, energy intake, carbohydrate, fat, protein intake, education, smoking, physical activity Serving sizes based on US Department of Agriculture Food Composition Table. Categorized in quartiles based on phytochemical index score: • <20.9 (Reference) • 20.9-28.3 • 28.4037.1 • >37.1	Every one increase in vegetable serving associated with weight reduction in 3y: Quartiles: 1- Reference 2- 0.15kg 3- 0.32kg 4- 1.01kg Every one increase in fruit servings associated with weight reduction in 3y: 1- Reference 2- 0.77kg 3- 0.71kg 4- 1.19kg

Study	Country	Aim	Methods	Relationship between body composition and fruit and vegetable intake
Systematic Review				
(Mytton et al., 2014)	India, USA, Scotland • 1026 adult men and women.	To evaluate the relationship between fruit and vegetable intake, energy intake and body weight.	Eight randomised controlled trials averaging 14.7 weeks. High and low arms of fruit and vegetable intake had at least 50g difference although the range of fruit and vegetable intake varied. Adjusted for energy intake.	Mean change in body weight was 0.68kg decrease for those in “high fruit and vegetable intake” arms of the studies. Impact of increased fruit and vegetables on weight gain/loss ranged from (-4.41 to 0.40).

The importance of dietary Fibre

Fruits and vegetables can impact obesity due to their high dietary fibre content. Studies have shown an inverse association between dietary fibre consumption and body composition (Slavin, 2005). Dietary fibre includes both soluble fibre - defined by water solubility and includes pectin, gum and mucilage, and insoluble fibre - defined as insoluble in water and include cellulose, hemicellulose and lignin (Cui et al., 2019). These impact a range of weight-related physiological mechanisms through structural, physiological, hormonal and microbiomic effects.

Dietary fibre can promote satiety and prolong satiation; subsequently reducing the likelihood of excess energy intake (Howarth et al., 2001). Wanders et al. (2014) showed the addition of fruit fibre pectin to meals resulted in reduced hunger and overall energy intake when compared to the control. The structure of fibrous foods requires increased time for all body processes, starting with increased chewing time (Dreher and Ford, 2020), digestion time and movement through the body (Cruz-Requena et al, 2016). Soluble fibre forms a viscous gel that increases gastric distention and slows gastric emptying. This distension for a prolonged period of time leads to prolonged stimulation of afferent vagal nerves (Howarth et al., 2001) and a prolonged sense of satiety (Marciani et al., 2000). The slow movement through the gastrointestinal tract results in slower absorption of nutrients into the blood stream (Cruz-Requena et al, 2016), therefore prolonged action on arcuate nucleus and prolonged satiation (Baqai and Wilding, 2014). The slower absorption also results in a reduced post-prandial glycaemic response, putting less strain on the pancreas to release insulin which is a promotor of energy storage (Cruz-Requena et al, 2016). Soluble fibre can physically trap macronutrients such as free sugars in a viscous gel and impair the contact between the nutrient and the intestinal cell villi (Cui et al., 2019), thus impairing absorption of energy contributing nutrients and reducing energy storage. Therefore, a lower energy, high fibre meal can lead to an individual feeling satiated for longer resulting in a lower energy intake when compared to a higher energy, low fibre meal of the same weight (Howarth et al., 2001).

Insoluble fibre increases bulk resulting in increased gastric distention and satiety. However, insoluble fibre speeds movement of nutrients through the gastrointestinal tract. This results in reduced contact time between nutrients and the brush border; ultimately leading to reduced energy absorption (Cui et al., 2019).

The fibre from fruit and vegetables also influence adiposity through shaping the gut microbiome. An individual's microbiome consists of a range of bacterial cells in an approximate 1:1 ratio with our own cells (Wilson et al, 2020). These bacteria produce metabolites which feed into our metabolic pathways (Wilson et al, 2020). There is a diverse range of gut microbes however the most prevalent bacterial groups are Firmicutes and Bacteroidetes (Reynolds et al., 2019). A higher Firmicute-to-Bacteriodete ratio, or dysbiosis, is associated with reduced gut barrier function as permeability increases (Davis, 2018). This results in bacterial movement into the bloodstream leading to low-grade inflammation (Cui et al., 2019). Dysbiosis also results in altered production of metabolites that are essential for human health (Davis, 2018). The composition has been found to differ between lean and obese individuals (Dominianni et al., 2015), where obese individuals (Magne et al., 2020) are likely to have lower gut microbiota diversity with a higher firmicute-to-bacteroidetes ratio (Davis, 2018). A diet high in fruits and vegetables are useful as it promotes a reduced concentration of firmicutes (Santos et al., 2019).

Around 40% of fibre is fermented in the colon by bacteria to produce SCFA and peptides (Davis, 2018). The three main SCFA are butyrate, propionate, and acetate (Wilson et al, 2020). Propionate activates anorexogenic hormones such as leptin by acting on the GPR41 receptor in adipose tissue thereby acting on the appetite centre of the brain and increasing satiety (Cui et al., 2019, Davis, 2018). Butyrate can enhance immunity by reducing inflammation and activating immune pathways (Cui et al., 2019). Acetate is commonly used by the liver for gluconeogenesis and de novo lipogenesis and is considered obesogenic as it promotes production of the hormone ghrelin which increases appetite and promotes obesity (Davis, 2018). Butyrate and Propionate are potent stimulators of the anti-obesogenic hormones GLP-1 and PYY. These hormones are released from entero-endocrine cells in response to SCFA, leading to slowed gastric emptying and acting on the arcuate nucleus to increase satiety (Graham et al., 2015, Cui et al., 2019). Increased circulating GLP-1 and PYY has been found in individuals after eating meals containing added fibre from fruits and vegetables, due to fermentation and production of SCFA (Hiel et al, 2019). Consequently, a higher intake of these foods may aid in reducing overall oral and energy intake (Sharma et al., 2016).

Low fibre diets can lead to dysbiosis and disproportional production of SCFA (Tannock and Liu, 2020). Low fibre diets promote the growth of Firmicutes (Sharma et al., 2016). Magne et al. (2020) reports firmicutes tend to produce more butyrate while bacteroidetes produce more acetate and propionate. Cui et al. (2019) suggests in a healthy microbiome, acetate can be utilized by other bacteria to form butyrate. Magne et al. (2020) also suggests that in obesity, butyrate-producing bacteria are replaced by other Firmicute bacteria resulting in a lower production of butyrate also. This would result in increased inflammation and reduced activation of POMC/CART meaning, reduced satiety and increased hunger (Magne et al., 2020). Studies have also shown higher concentrations of total faecal SCFA, particularly butyrate and propionate, in obese populations suggesting reduced absorption of these SCFA, therefore reduced appetite regulation (Graham et al., 2015).

Consuming fibre from a range of fruit and vegetables enhances the diversity of the gut microbiome (Dominianni et al., 2015). It is shown to promote the growth of colonies of bacteroidetes that produce anti-carcinogenic and anti-obesogenic SCFA such as butyrate, propionate and acetate (Cui et al., 2019). Fruit and vegetables provide a varying combination of insoluble and soluble fibres which are fermented at different rates. Soluble fibre, such as pectin commonly found in fruit such as apples, is more readily fermented than insoluble fibre. It, therefore, more strongly promotes growth of bifidobacterium, lactobacillus, and bacteroidetes (Cui et al., 2019), which are more prevalent in non-obese individuals (Kadsai et al, 2015), than less readily fermentable fibres. Therefore, not only the quantity, but also the diversity of an individual's fruit and vegetable intake, is important in influencing hunger and satiety messages and aiding the regulation of energy intake and consequently weight management.

Micronutrients and Phytochemicals

Fruit and vegetables impact body composition and metabolic health through their micronutrient, anti-oxidant and phytochemical composition. Fruit and vegetables provide essential compounds involved in energy utilization, lowering inflammation, and in preventing oxidative damage. Therefore, contributing to weight management and preventing obesity-related diseases (Aune et al., 2017).

Vitamins and Minerals

Micronutrients, found in fruit and vegetables, play key roles in energy utilization and in the regulation of the adipogenesis. A higher prevalence of micronutrient deficiencies has been found in obese populations (McKay et al., 2020, Garcia, 2012). This is firstly related to poor diet quality; particularly low intake of vitamin and mineral-rich foods such as fruit and vegetables, and high intake of energy-dense, nutrient-poor foods (McKay et al., 2020).

Many water-soluble vitamins found in fruit and vegetables, are intricately involved in utilizing energy. They are required to mobilize energy stores and to generate ATP via the TCA cycle and electron transport chain. B-vitamins, in particular thiamine, niacin, and riboflavin, play roles as cofactors in enzymatic reactions involved in the breakdown of carbohydrates, fats, and protein for energy while Vitamin C is key in the mobilization of stored long-chain fatty acids for beta oxidation to utilize for energy (Thomas-Valdes et al, 2016, McKay et al., 2020). Therefore, deficiency may result in impaired energy store mobilization and increased storage leading to adipose tissue hypertrophy and hyperplasia (Thomas-Valdes et al, 2016). There is an inverse relationship between vitamin C concentrations and central adiposity (Sharma et al., 2016). Thomas-Valdes et al (2016) found supplementing Vitamin C reduced inflammation in 75% of patients with obesity. A study of 50 Wistar rats on a high-fat diet, found supplementation with B vitamins lead to overall reduced body weight and lipid production. This was associated with elevated enzymatic activity (Zheng et al., 2018). It has also been theorized that vitamin deficiencies may result in ATP production being too slow to keep up with metabolic demands (Zheng et al., 2018) resulting in reduced utilization of storage. Thus, it is thought that micronutrient deficiencies may promote the desire to eat to gain nutritional sufficiency even once energy requirements are achieved (Thomas-Valdes et al, 2016). This may be due to continual hunger signalling, and consequently continued intake, as energy storage is not being adequately mobilised between eating episodes (Thomas-Valdes et al, 2016).

Obesity can amplify micronutrient deficiencies (Garcia, 2012). Already prevalent vitamin deficiencies can impair the quality of the mucosal wall, consequently inhibiting vitamin absorption (McKay et al., 2020). These vitamin deficiencies, along with low-grade inflammation of the intestine due to obesity, exacerbates poor absorption (McKay et al., 2020).

There is also evidence suggesting a correlation between excess adiposity and increased storage of fat-soluble vitamins such as vitamin D and vitamin A – therefore lower blood concentrations – despite no excessive intake (Garcia, 2012, Thomas-Valdes et al, 2016). Therefore, it is not surprising that fat soluble vitamin deficiencies, such as vitamin D and vitamin A, are prevalent among people that are obese (Garcia, 2012, Thomas-Valdes et al, 2016)   Precursors for Vitamin A such as beta-carotene are found in vegetables such as cruciferous vegetables, carrots, kumara, and green leafy vegetables. Vitamin A is involved in the regulation of adipogenesis and inflammation, as well as the downregulation of the T helper 1 cell (Th1) immune response. Therefore, Vitamin A deficiency leads to upregulation of Th1 cells which promote the production of pro-inflammatory cytokines such as TNFα, and increased circulation of leptin and resistin (Garcia, 2012). Vitamin A further inhibits the lipid storage capacity of adipocytes and the division of pre-adipocytes. Deficiency however, allows for higher expression of PPAR-y proteins which enable deposition of fat for storage (Garcia, 2012, Tyagi et al., 2011). Therefore, Vitamin A deficiency can promote growth and expansion of adipose tissue and increase weight (Garcia, 2012).

Although multiple studies have found correlations between vitamin deficiencies and obesity, there is limited research in humans to show that rectifying deficiencies via supplementation improves obesity (McKay et al., 2020). One randomized controlled trial showed a multivitamin supplementation reduced appetite but did not impact body weight (Major et al., 2008). A cross-sectional analysis by Araghi et al. (2019) found every one nmol/L increase in serum folate was associated with a 0.021kg/m^2 reduction in BMI, however no correlation between supplementation and weight loss was found. In contrast, many studies, shown in table 2, have found correlations between nutrient-rich fruits and vegetables intakes and reduced weight. For example, Ozato et al. (2019), found diets high in vitamins and in minerals from high vegetable intakes were associated with low rates of obesity.

Dysbiosis can also lead to impaired absorption of minerals due to a higher pH in the colon (Cui et al., 2019). Deficiency of minerals such as potassium and magnesium, which are found in fruit and vegetables, can also influence energy metabolism (McKay et al., 2020). For example, Potassium is essential in the generation of ATP through the electrochemical gradient caused by potassium being pumped into the cell. Obesity can alter this potassium channel leading to low serum potassium levels and impaired insulin secretion therefore impaired carbohydrate utilisation (McKay et al., 2020) Adequate daily potassium intakes have been shown to reduce the risk of obesity and to have an inverse correlation with visceral adiposity (Cai et al., 2016, Ozato et al., 2019).

Magnesium is found in green leafy vegetables and is a cofactor for the enzymes involved in glycolysis, beta oxidation, and protein synthesis (Saris et al., 2000). Adequate magnesium is needed to utilise energy stores and the subsequent glucose that is produced. It is not surprising, then, that studies have found correlations between low serum magnesium and increased visceral adiposity, insulin resistance, risk of metabolic syndrome and inflammation (Lu et al., 2020, McKay et al., 2020, Ozato et al., 2019).

Phytochemicals

Phytochemicals are compounds from plant foods that have varying health benefits. They can be anti-oxidants, anti-carcinogens, and anti-inflammatory, therefore aiding in the protection against non-communicable diseases. Common phytochemicals found in fruits and vegetables are flavonoids, alkaloids, and phenols.

Phytochemicals in fruit and vegetables are important in the adipocyte lifecycle and the regulation of satiety (Table 2.3). They are involved in the up-regulation of genes required for lipolysis and the down regulation of genes involved in lipogenesis and adipogenesis (Mirmiran et al., 2012, Meydani and Hasan, 2010, Mukherjee et al., 2015). Through this, dietary phytochemicals inhibit adipogenesis, reduce storage of fats and promote adipocyte apoptosis (Mukherjee et al., 2015). A systematic review by Carnauba et al. (2017) found higher intake of phytochemical-rich foods was associated with a lower BMI, BF% and WC. Bertoia et al. (2016)

found increased intake of foods rich in flavanols and anthocyanins was inversely associated with weight gain over four years after adjusting for lifestyle factor.

Phytochemicals, such as anthocyanins, are antioxidants which intercept and neutralise the ROS produced as a by-product of metabolism, cell apoptosis and that increase with expanding adipose, thus reducing low-grade inflammation (Wallace et al., 2019).

Table 2.3: Phytochemicals and adiposity

Phytochemical	Food	Functions
Flavonoids		
Flavanols	• Citrus fruits • Allium vegetables • Cruciferous vegetables • Berries	Promotes weight loss • *Decreased body weight by 4.6% and WC by 4.48% in humans given catchenin extract over 3 months (Gonzalez-Castejon and Rodriguez-Casado, 2011, Meydani and Hasan, 2010)* Inhibits adipogenesis • *Exposure of pre-adipocytes to quercetin attenuated adipogenesis through upregulation of AMPK (Gonzalez-Castejon and Rodriguez-Casado, 2011)* Promotes adipocyte apoptosis • *Apoptosis of in vitro mature adipocytes increased when incubated with quercetin (Zhao et al, 2017)* Reduces lipid accumulation • *Rutin treatment in human hepatocarcinoma cells supressed fatty acid synthase gene expression resulting in lower lipid accumulation (Wu et al., 2011)* Improves microbial dysbiosis associated with obesity • *High-fat diet fed rats treated with quercetin had improved SCFA production, improved gut barrier and decreased Firmicute-to-Bacteriodete ratio (Liu et al., 2020)* Promotes thermogenesis *Green tea extract containing 50mg caffeine and 90mg epigallocatechin increased 24-h energy expenditure through thermogenesis by 4% in 24-hours in 10 men compared to placebo (Dulloo et al, 1999)*
Anthocyanins	• Berries, • Leafy Vegetables • Root vegetables	Inhibit adipogenesis • *Decreased adipocyte-associated markers PPARγ, SREBP1c expression in 3T3-L1 cell line and inhibited adipocyte differentiation (Suzuki et al, 2011)* Increases lipolysis • *Increased lipoprotein lipase and AMP-activated protein kinase in rats supplemented with anthocyanins(Wu et al, 2013)* Decreases fat accumulation • *Decreased lipogenesis gene acetyl-CoA carboxylase expressed in rats supplemented with anthocyanins (Lee et al., 2014)* Promotes weight loss *Rats fed a high fat diet and supplemented 2.9mg/g of blueberry anthocyanins from decreased body and adipose tissue weight compared to control (Meydani and Hasan, 2010)*
Flavanones	• Citrus fruits	Inhibits adipogenesis • *Supplementation of hesperidin in rats lead to reduced central obesity and impaired differentiation of 3T3-L1 pre-adipocytes in vitro (Xiong et al, 2019)* Inhibits absorption of fats *Isolated Hesperidin inhibited activity of Pancreatic Lipase in rats (Kim et al, 2016)*

Alkaloids		
	• Red peppers	Increases Satiety *Capsaicin added to a lunch meal reduced the expression of Ghrelin and promoted the expression of GLP-1 in humans when compared to a control*
	• Cruciferous vegetables	Inhibition of adipocyte differentiation • *Mice given 0.1% sulforaphane for 6 weeks had blunted weight gain compared to control mice (Martins et al., 2018)* • *3T3-L1 pre-adipocytes treated with 20umol/L of sulforaphane had reduced differentiation compared to control.(Martins et al., 2018)* Reduced lipid accumulation *3T3-L1 pre-adipocyte cells treated with 20umol/L of sulforaphane had lower concentration of lipid droplets and triglycerides than the control (Martins et al., 2018)*
Phenols		
	• Grapes • Berries	Increases lipolysis • *Resveratrol supplementation in mice led to increased phosphorylation of AMPK leading to up-regulation in FA oxidation (Mir et al., 2019)* Reduces lipogenesis and lipid accumulation • *In vitro mature 3T3-L1 adipocytes treated with 25uM of resveratrol had significantly decreased lipid accumulation and down-regulation of lipogenic genes (Rayalam et al, 2008)* • *Up-regulation of mitochondrial biogenesis and oxidative phosphorylation leading to supressed lipid accumulation (Meydani and Hasan, 2010)* Promotes weight loss *A randomized controlled trial of 1500mg of resveratrol for 90 days significantly lowered BMI, weight, BF% and WC in humans (Zhao et al, 2017)*

Table developed from (Liu et al., 2020, Wu et al., 2011, Mir et al., 2019, Zhou et al., 2019, Gonzalez-Castejon and Rodriguez-Casado, 2011, Meydani and Hasan, 2010, Stuby et al., 2019, Martins et al., 2018, Williams et al., 2013, Lee et al., 2014, Kim et al, 2016, Rayalam et al, 2008)

Patterns of Fruit and Vegetable Intake

The quantity, type, diversity, and distribution of fruit and vegetables in the diet contribute to the impact on body composition. Wilunda et al. (2020), found having fruits and vegetables with a meal reduced the intake of energy-dense foods however eating fruits and vegetables between or after meals was associated with overall increased calories without reducing the calories from energy-dense, nutrient poor foods. In their study, vegetables were more likely to be incorporated into a meal thereby replacing higher energy foods, while fruits tended to be eaten as a snack, therefore increasing total energy intake (Wilunda et al., 2020, Nour et al., 2018). Hakim et al. (2019) found fruit increased GLP-1 when eaten before a meal, thereby reducing intake. Mytton et al. (2014) found large portion sizes of fruits or vegetables could add to the calorie intake if consumed additionally to an individual's current diet. Therefore, it is the exchange of energy- dense food for more fruit and vegetables that can reduce the risk of obesity and obesity-related diseases due to reduced saturated fat, salt, and sugar intakes.

Furthermore, studies have found the preparation of fruits and vegetables may influence satiety and body composition (Houchins et al., 2013). Houchins et al. (2012) found participants who had fruit and vegetables in a beverage form were more likely to have higher energy intakes and gain weight. This is suggested to be due to reduced fibre and weaker satiety signalling (Dreher and Ford, 2020). Common cooking methods can differ between cultures and can affect the energy-density of fruit and vegetables. Lako and Nguyen (2001) showed a common method for cooking vegetables in a Fijian diet was boiling in coconut cream. They also found Pacific were more likely to fry vegetables in butter than NZE. However, NZE participants were more likely to roast in oil where Pacific were more likely to dry roast. These differences affect total energy intake and energy balance.

Because of the differences in nutrient composition of fruit and vegetables, consuming a diverse range is associated with a healthy diet (Nour et al., 2018). Diversity ensures a range of micronutrients and phytochemicals and maintains a healthy gut microbial composition (Wallace et al., 2019). Therefore, it is important to know how the range of fruit and vegetables consumed differ between those with normal and obese BMI's (Dreher and Ford, 2020). Dried fruits have reduced water content and therefore have higher energy density. Starchy vegetables such as potato and sweetcorn have a high carbohydrate content and have been associated with increased risk of weight gain (Dreher and Ford, 2020). Mackay et al. (2018) showed that the proportions of certain fruits or vegetables differ between cultures. For example, consumption of taro, green banana, and onion, yam were more prevalent in Pacific diets while potatoes, brassicaceae and berries where more common in a NZE diet. However, it is not known how they influence body composition.

Tobias et al. (2006) found a direct inverse relationship between deprivation and WC and BMI in non-Māori females although not in Māori. Non-Māori females showed a strong positive relationship between income and BMI and WC although not in Māori. There are many contributors to this relationship, including increased stress associated with increased deprivation leading to cortisol hormone release thus promoting weight gain (Marmot and Wilkinson, 2005). However, diet has been shown to be significantly impacted by deprivation and income levels and a contributor to obesity. Those with higher deprivation tend to consume more energy-dense nutrient-poor foods and less fruits, vegetables and wholegrains.(McGill et al, 2015). Ball et al. (2005) found women of low SES were less likely to choose foods on the basis of health and this was associated with lower fruit and vegetable consumption than women of a high SES. Therefore, when evaluating fruit and vegetable intake on body composition, deprivation must be accounted for.

The WHO and World Cancer Research Fund (WCRF) currently recommend a minimum of 400g of non-starchy fruits and vegetables, or at least five servings, for the prevention of non-communicable diseases such as some cancers, CVD and T2DM (World Health Organization, 2018, World Cancer Research Fund and American Institude for Cancer Research, 2018). The WCRF also recommends at least 30g of fibre per day to reduce cancer risk (World Cancer Research Fund and American Institude for Cancer Research, 2018). Up until November 2020, the NZ Ministry of Health (MoH) recommended at least three 80g portions of vegetables and two 80g portions of fruit per day, equivalent to five serves and 400g/day (Ministry of Health, 2018). In the new guidelines released in December 2020, this has increased to five 75g servings of vegetables and two 150g servings of fruit for women, which is equivalent to 675g/day (Ministry of Health, 2020b). The MoH also recommends 25g of dietary fibre per day (Ministry of Health, 2015b). For heart health, the Heart Foundation currently recommends three to four 80g serves each of fruit and vegetables, equivalent to 480-640g/day (Heart Foundation, 2018).

Despite the significant health benefits of consuming fruit and vegetables, the recent NZ National Health Survey identified an average of only 26.4% of Pacific and 35.3% of NZE, are meeting the previous recommended guidelines of three servings of vegetables and two servings of fruit (Ministry of Health, 2019). Of the Pacific population in NZ, 42.3% consumed the recommended three servings of vegetables per day and 47.8% consumed the recommended two servings of fruit per day, compared to the NZE population consuming 57.6% and 52.9% respectively. Unfortunately, it is not yet known the influence these intakes are having on body composition in Pacific and NZE women living in NZ.

The Predictors Linking Obesity and the Gut Microbiome (PROMISE) study (Kindleysides et al, 2019) provides data on dietary intake and patterns concerning fruit and vegetables along with body composition measurements in both NZE and Pacific women. Analysing this data will provide greater depth of insight to the relationship between fruit and vegetables and obesity in order to develop suitable and relevant recommendations in the future.

Chapter 3: Research Manuscript

Abstract

Background: Obesity is a significant health issue related to diet. Fruit and vegetables are low-calorie, nutrient rich foods thought to positively influence body composition. Little is known about current fruit and vegetable consumption in Pacific and New Zealand European (NZE) women.

Aim: To conduct an in-depth investigation of fruit and vegetable intake (quantity, quality and habits) of NZE and Pacific women participating in the PROMISE study to determine links with body composition outcomes.

Methods: Cross-sectional study of 161 NZE and 142 Pacific healthy, obese and non-obese women aged 18-45 years living in Auckland, New Zealand. Fruit and vegetable intakes were analysed using a five-day food record (5d-FR) and seven-day Dietary Diversity Questionnaire (DDQ). Body composition measurements were taken using ISAK protocol measurements and DXA scanning. Spearman's rho correlation coefficient and a multiple stepwise enter method linear regressions was used to analyse the relationship of fruit and vegetable serves and body composition.

Results: Total daily fruit and vegetable and vegetable servings only were inversely correlated with BMI (-0.15, -0.16) and BF% (-0.21, -0.20) respectively. Every one serve (75g) of vegetables significantly predicted a 0.65kg/m^2 reduction in BMI and 1.16% in BF% for women combined. Pacific and NZE women were not eating the recommended vegetable (73.9%, 84.5%) or fruit servings (73.2%, 48.4%) respectively, despite BMI or BF%. Obese and normal NZE respectively consumed more yellow vitamin-A-rich and cruciferous than Pacific who consumed more starchy vegetables. Pacific women's highest intake was later (Lunch, Afternoon tea, Dinner) than NZE (Breakfast, Lunch, Dinner). Most consumed fruits

or vegetables for both ethnicities were carrots, onions, lettuce, tomatoes and potato. Pacific women had higher carbohydrate and lower fibre intake from fruit and vegetables than NZE in the obese BMI category.

Conclusions: Daily serves of fruit and vegetables are significantly correlated with body composition although overall intake is low. Pacific and NZE women have significant differences in fruit and vegetable intake, consumption patterns and nutrient intakes.

Introduction

Obesity is a major health concern in New Zealand (NZ) affecting one in three (1.22 million) adults and is disproportionally more prevalent in Pacific (67%) than New Zealand European (NZE) (33%) adults (Ministry of Health, 2020a). Obesity is a major, and modifiable, risk factor for cardiovascular disease (CVD), type 2 diabetes (T2DM), some cancers, infertility, gout, sleep apnoea and arthritis (World Health Organization, 2020b).

Diet is a major modifiable component in the aetiology of obesity (Baqai and Wilding, 2014). Fruit and vegetables are low-energy, nutrient-rich foods that aid in reducing overall energy intake, regulating hunger and satiety, modifying the gut microbiome and providing micronutrients and phytochemicals involved regulating adipogenesis. The Ministry of Health (2020b) (MoH) has recently (December 2020) updated their recommendations for fruit and vegetable intakes from the equivalent of 400g to 675g daily for women to reduce the risk of obesity and obesity-related diseases. However, in addition to quality, consumption patterns – quantity, type, diversity and distribution – may further influence the impact of fruits and vegetables on body composition (Wilunda et al., 2020, Nour et al., 2018, Sharma et al., 2016).

The NZ health survey identifies quantity of fruit and vegetables consumed. However, the fruit and vegetable consumption patterns, such as type, preparation and distribution throughout the day, of NZE and Pacific women in NZ, and the influence on body composition, are not currently known. This study seeks to investigate these patterns of fruit and vegetable intake among NZE and Pacific women of different BMI and BF% categories in order to identify potential links and make relevant recommendations to support the new serving size guidelines and aid in reducing obesity in NZ women.

Methods

This study is a sub-study of the PRedictors linking Obesity and the gut MIcrobiomE (PROMISE) study. The PROMISE study is a cross sectional analysis of diet, the gut microbiome and body fat profiles of women in the Auckland region with the aim of providing data to better understand the aetiology of obesity (Kindleysides et al, 2019). Metabolically healthy women aged from 18 to 45 years old of Pacific and NZE ethnicity in Auckland were involved in this study. Participants were recruited into either normal BMI (18.5-24.9kg/m^2) or obese BMI (≥30kg/m^2) categories. A total of 303 women were included in this study including 142 Pacific women and 161 NZE women.

Ethics approval was granted by the Southern Health and Disability Ethics Committee (16/STH/32) and the study was registered at anzctr.org.au (ACTRN12618000432213).

Inclusion criteria for PROMISE study were: women aged 18 – 45years, NZE or Pacific ethnicity, generally healthy with no underlying chronic health conditions, not pregnant or breastfeeding in the last six months and no previous bariatric surgery. Inclusion criteria for this sub-study were all of the above and: a BMI ≥ 18.5, Body Fat Percentage (BF%) >10% (as deemed essential fat by (American Council of Exercise, 2021), completed at least three days of the 5d-FR, completed the seven-day DDQ, and completed the body composition measures. Forty-six participants dropped out of the study. Exclusions are noted in Diagram 1.

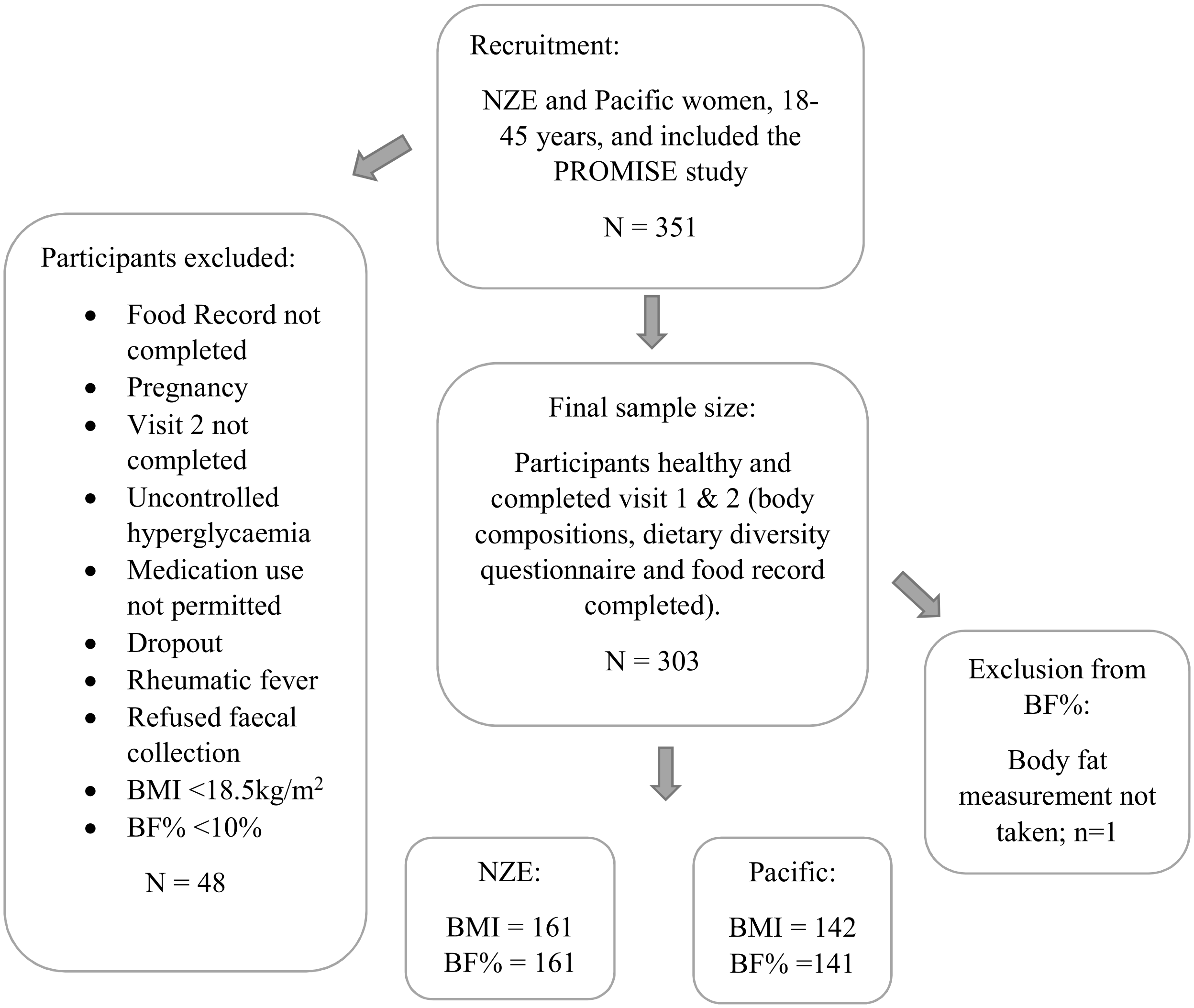

Diagram 1: Flow diagram of sub study participant inclusion

All participant data used for this analysis were collected as part of the PROMISE study protocol (Kindleysides et al, 2019). Data required for analysis included ethnicity, age, deprivation score, weight, BMI, BF%, waist circumference (WC), height, and sagittal height. Dietary data included a 5d-FR and a 7-day DDQ and was collected across all seasons. Deprivation scores were obtained from the New Zealand Deprivation Index 2013 (NZDep2013) meshblocks (Kindleysides et al, 2019).

Anthropometry

Measurements included height, fasting weight and waist and hip circumference. Measures were conducted using ISAK: International Society for the Advancement of Kinanthropometry protocol (Stewart et al., 2011). All researchers were level 1 ISAK trained. Body Mass Index was calculated using the Quetelet index (weight(kg)/height(m)^2) (Garrow and Webster, 1985). Waist and hip circumference were measured using Lufkin W600PM flexible steel tape. Participants stood in a relaxed position with arms folded across their chest. Waist to hip ratio (WHR) was calculated as waist circumference (cm) divided by hip circumference (cm). Sagittal abdominal diameter was assessed in a supine position with the measurement at the umbilicus level using Holtain-Kahn Abdominal Calliper.. Body composition measurements were performed using dual-energy x-ray absorptiometry (DXA; Hologic QDR Discovery A, Hologic Inc. with APEX V. 3.2 software) for total and regional body mass and body fat. All staff who used DEXA scanning had Australian and NZ bone mineral Society clinical densitometry accreditation.

Using the data obtained, participants in each ethnicity were grouped into the following categories:

1. BMI (World Health Organization, 2020a)
    a. Normal BMI (18.5-24.9kg/m^2)
    b. Overweight BMI (25.0-29.9kg/m^2)
    c. Obese BMI (30kg/m^2)
2. BF% (Oliveros et al., 2014)
    a. Normal BF% (<35%)
    b. High BF% (≥35%)

Dietary Data

A 5d-FR, including three weekdays and two weekend days, was self-reported by participants to report total dietary intake. All participants were given training in how to estimate and record dietary intake. Once completed, participants received a one-to-one interview with a NZ-registered Dietitian to clarify portion sizes, timing and/or patterns of intake and to identify potential missed items. A 7-day yes/no DDQ was completed by participants at the second visit to identify diversity of intake and covered the 5d-FR time frame. The fruit and vegetable sections of this questionnaire were used in this study to identify diversity of intake.

Dietary data analysis from the 5d-FR was performed using Foodworks 10 (Xyris Software Pty Ltd) dietary analysis software. FOODfiles 2016 (developed by the NZ institute for Plant & Food Research and the NZ Ministry of Health), along with AusFoods 2017 and AusBrands 2017 (developed by the Food Standards Australia New Zealand and based on AUSNUT 2011-13 Australian food composition databases) are used by this software for the nutrient analysis of foods. All data were previously entered as part of the PROMISE study by registered dietitians, however all food diary entries into Foodworks were re-assessed and compared with the originals for quantity, type and timing to assure no errors were present. All measurements followed the metric system. Custom recipes were checked for accuracy and where present, full servings of fruit and vegetables were removed from custom recipes to allow individual quantification. Any further fruit or vegetables within the recipe remained in the custom recipe and was analysed as a mixed meal. Once approved, Foodworks files were exported into Microsoft excel for data processing (Microsoft Corporation, 2018).

In Microsoft Excel, data were edited to isolate fruit and vegetables. All other food items not containing fruit or vegetables were deleted. Where fruit or vegetables were present but unidentifiable, foods were categorised as mixed meals. Fruits and vegetables were then categorized into the corresponding groups outlined in Appendix A: Supplementary methods table 2.

Fruit and vegetable servings were defined as 75g of vegetables and 150g of fruit, based on the Eating and activity Guidelines for NZ Adults published by the Ministry of Health (2020b). This is the equivalent of half a cup of cooked or canned vegetables, half a medium potato or one cup of leafy green vegetables, and the equivalent of one medium apple or banana, two small stone fruits, one cup of canned, diced or frozen fruits.

For mixed meals where fruit or vegetable serving size was less clear, conversion factors were used to isolate the serving percentage. For mixed meals with the recipe present, the total weight of fruit or vegetables in the recipe were summed and divided by the total food weight of the recipe. Other standardized conversions were estimated either by searching the Countdown supermarket online website for reference products or, if the mixed meal was a FW option, manual FW entries of similar dishes were used as an estimate. Conversion factors are outlined in Appendix A: Supplementary methods table 1.

Meal times were defined by clock times (Appendix A: Supplementary methods table 3) with the assumption of three regular energy intake peaks (Fayet and Mortensen, 2012). This prevents participant-defined 'snacking' which occurs in self-reported meal times and has the potential to be more calorie-dense than participant defined 'meals' (Fayet-Moore et al., 2017). Fruit and vegetables were then categorised into seven periods based on the corresponding clock-time given by the participant.

Average intake of fruit or vegetable servings by fruit and vegetable category was calculated by dividing total 5d-FR average intake in grams by the appropriate servings size; either 75g or 150g. Finally, the total sum of nutrient intake, total servings, servings per mealtime and servings within categories were divided by the number of days from the participants corresponding food diary to find an average. The data were then imported into SPSS for statistical analysis.

Data analysis

Data were analysed using IBM SPSS Statistics version 27 (IBM Corp, 2020). Normality of data were tested using Kolmogorov-Smirnov and Shapiro-Wilk tests with significance ≥0.05 indicating normality. Non-parametric data were log-transformed and if not-normally distributed or where appropriate in order to carry out further statistical analysis, reported as untransformed median (25th percentile, 75th percentile). A high proportion of data (BMI, BF% and fruit and vegetable intake) were not normally distributed, therefore, to enable comparisons, all data were presented as non-parametric data. Categorical data were reported as counts and frequencies.

Differences between ethnicity and BMI groups and ethnicity and BF% groups were analysed by a Kruskal-Wallis and Mann-Whitney U test for non-parametric data and a one-way ANOVA for parametric data. Post-hoc analyses were used to detect where differences lay. A pair-wise comparison with Bonferroni correction was used for the Kruskal-Wallis testing with significance at <0.05. Tukey's post hoc test was used for normally-distributed data with significance at <0.05.

Percentage contribution of nutrients from fruit and vegetables to the total intake of nutrients was calculated by dividing nutrients from fruit and vegetables only for all participants by total nutrients and testing for normality to report averages.

Due to the prevalence of non-parametric data, Spearman's Rho was used to identify correlations between fruit and vegetable serves and body composition data. Multiple linear regressions (step-wise enter method) were used to evaluate fruit and vegetable serves as predictors of BMI and BF%. Assumptions were met for auto-correlation, multi-collinearity, homoscedasticity, linearity and normality. Age, ethnicity and deprivation were controlled for.

Results

Participant Characteristics

Of the 303 women in this study, 142 were of Pacific ethnicity and 161 were NZE. Pacific women were significantly younger than NZE in both the obese (23y versus35y respectively) and normal BMI (22y versus 30y respectively) categories. Pacific women had higher rates of deprivation than NZE (Figure 3.1). For NZE, obesity rates increased as deprivation increased until deprivation score five. It then reduced with further increasing deprivation as participant numbers reduced. For Pacific, both normal and obese BMI groups increased with increasing deprivation due to overall higher prevalence of deprivation

Overall, 48.2% of the women in this study had an obese BMI, (Pacific=52.8%, NZE=44.1%), and 37.6% had a normal BMI (Pacific=25.4%, NZE=48.4%). Body fat percentage was significantly higher in women with an obese than normal BMI in both Pacific (42.7% versus 28.1%; P<0.01) and NZE (44.3% versus 25.3%; P<0.01). Muscle mass and fat mass were significantly different between all BMI categories within each ethnicity (Table 3.1). Waist circumference measurements were different between most BMI groups within ethnicities (except overweight and normal NZE) and between Pacific and NZE women with the obese BMI category (98.1(92.5-111) cm versus 72.8 (69.5-75.4) cm, respectively. Sagittal height was higher in women with an obese than normal BMI in both Pacific and NZE.

BMI was only different in Pacific women with a normal BF% (24.4 (23.2, 26.4) than NZE (22.5 (21.1, 23.5). Waist Circumference, sagittal height and muscle mass were higher in women with a high BF% than a normal BF% in both Pacific and NZE. Between ethnicities, Pacific women had higher muscle mass, WC, and sagittal height than NZE for high and normal BF%.

Table 3.1: Descriptives

	BMI; Pacific n=142				BMI; NZE n=161				
Descriptives	**Obese n=75(24.8%)** median (25-75)	**Overweight n=31(10.0%)** median (25-75)	**Normal n=36(11.9%)** median (25-75)	**p-value^**	**Obese n=71(23.4%)** median (25-75)	**Overweight n=12(3.9%)** median (25-75)	**Normal n=78(25.7%)** median (25-75)	**p-value^**	**p-value***
Age	23 (21-29)[g]	23 (21-29)	22 (19-26)[h]	0.13	35 (28-40)[dg]	26 (23-35)	30 (25-36)[dh]	**<0.01**	**<0.01**
Height	168 (164-173)	169 (165-173)	169 (164 -174)	0.47	167 (164-172)	165 (163-167)	167 (164-171)	0.35	0.23
Weight	100 (90.5-113)[a]	77.7 (72.4-84.9)[a]	67.3 (61.9-72.3)[a]	**<0.01**	96.0 (87.9-102)[d]	71.1 (68.6-74.6)[d]	61.4 (58.1-65.8)[d]	**<0.01**	**<0.01**
BMI	35.2 (32.3-40.3)[a]	27.3 (25.8-28.6)[a]	23.6 (21.8-24.2)[a]	**<0.01**	33.6 (31.8-36.6)[d]	25.4 (25.1-26.8)[d]	22.2 (20.9-23)[d]	**<0.01**	**<0.01**
Muscle mass	32.1 (29.7-35.9)[ag]	29.3 (26.2-32.2)[a]	26.4(23.9-28.9)[a]	**<0.01**	29.7 (27.4-32.6)[deg]	27.0 (26.4-29.1)[d]	25.5 (22.9-26.9)[e]	**<0.01**	**<0.01**
Fat mass	42.3 (36.9-54.3)[a]	25.1 (23.1-29.7)[a]	18.6 (16.5-22.0)[a]	**<0.01**	41.2 (36.7-48.8)[d]	22.3 (21.0-24.6)[d]	15.1 (12.9-18.5)[d]	**<0.01**	**<0.01**
Body fat %	42.7 (40.1-48.9)[a]	32.8 (31.0-35.1)[a]	28.1 (23.9-32.2)[a]	**<0.01**	44.3 (40.1-47.7)[d]	31.3 (28.4-34.8)[d]	25.3 (21.0-29.2)[d]	**<0.01**	**<0.01**
Waist circumference (cm)	98.1 (92.5-111)[ag]	83.3 (78.6-85.6)[a]	75.3 (72.3-77.5)[a]	**<0.01**	97.7 (92.7-104)[deg]	76.8 (75.2-83.1)[d]	72.8 (69.5-75.4)[e]	**<0.01**	**<0.01**
Hip circumference (cm)	120 (115-131)[a]	109 (106-112)[a]	102 (97.7-103)[a]	**<0.01**	121 (116-127)[de]	106 (102-110)[d]	97.6 (93.8-101)[e]	**<0.01**	**<0.01**
WHR	0.82 (0.78-0.86)[ab]	0.76 (0.73-0.80)[a]	0.75 (0.72-0.76)[bg]	**<0.01**	0.82 (0.78-0.86)[g]	0.73 (0.72-0.77)	0.74 (0.72-0.78)	**<0.01**	**<0.01**
WHtR	0.59 (0.53-0.67)[ag]	0.46 (0.44-0.48)[a]	0.39 (0.37-0.41)[a]	**<0.01**	0.56 (0.53-0.62)[dg]	0.43 (0.41-0.45)[d]	0.37 (0.35-0.39)[d]	**<0.01**	**<0.01**
Sagittal height	24.6 (22.8-27.5)[a]	20.3 (19.3-21.0)[a]	17.9 (17.1-18.2)[a]	**<0.01**	23.3 (21.9-25.0)[de]	18.7 (18.5-19.0)[d]	17.3 (16.4-18.0)[e]	**<0.01**	**<0.01**

	BF%; Pacific=141			BF%; NZE=161			
	Normal BF% n=56 Median (25, 75)	**High BF% n=85 Median (25, 75)**	**P-value^ Within ethnicity**	**Normal BF% n=66 Median (25, 75)**	**High BF% n=95 Median (25, 75)**	**P-value^ Within ethnicity**	**P-value* Between ethnicity**
Age	23 (20, 27)[c]	23 (21, 29)[d]	0.15	29 (24, 36)[bc]	35 (28, 40)[bd]	**<0.01**	**<0.01**
Height	170 (165, 175)[ac]	167 (164, 172)[a]	**0.03**	168 (164, 171)[c]	167 (162, 172)	0.63	**0.03**
Weight	72.3 (66.6, 77.6)[ac]	96.6 (84.2, 110)[a]	**<0.01**	63.8 (58.6, 66.7)[bc]	94.9 (87.7, 102)[b]	**<0.01**	**<0.01**
BMI	24.4 (23.2, 26.4)[ac]	34.2 (31.1, 39.8)[a]	**<0.01**	22.5 (21.1, 23.5)[bc]	33.5 (31.8, 36.4)[b]	**<0.01**	**<0.01**
Muscle mass	28.2 (25.6, 31.6)[ac]	31.0 (28.2, 34.5)[ad]	**<0.01**	26.0 (23.5, 27.4)[bc]	26.6 (32.4, 31.0)[bd]	**<0.01**	**<0.01**
Fat mass	21.9 (17.3, 23.9)[ac]	40.9 (34.3, 52.7)[a]	**<0.01**	16.4 (13.3, 19.4)[bc]	40.6 (36.2, 48.8)[b]	**<0.01**	**<0.01**
Body fat %	30.3 (26.0, 32.5)[a]	41.8 (39.7, 48.4)[a]	**<0.01**	26.6 (21.5, 29.8)[b]	44.2 (40.0, 47.6)[b]	**<0.01**	**<0.01**
Waist circumference (cm)	77.3 (72.8, 82.3)[ac]	96.8 (89.0, 107)[a]	**<0.01**	73.1 (69.6, 76.0)[bc]	97.2 (92.2, 103)[b]	**<0.01**	**<0.01**
Hip circumference (cm)	104 (100, 109)[ac]	118 (113, 129)[a]	**<0.01**	98.9 (94.5, 102)[bc]	121 (115, 127)[b]	**<0.01**	**<0.01**
WHR	0.75 (0.71, 0.77)[a]	0.80 (0.76, 0.85)[a]	**<0.01**	0.73 (0.72, 0.78)[b]	0.82 (0.78, 0.86)b	**<0.01**	**<0.01**
WHtR	0.42 (0.39, 0.45)[ac]	0.58 (0.52, 0.66)[a]	**<0.01**	0.37 (0.35, 0.40)[bc]	0.56 (0.53, 0.62)[b]	**<0.01**	**<0.01**
Sagittal height	18.3 (17.4, 20.0)[ac]	24.4 (22.3, 27.3)[a]	**<0.01**	17.4 (16.5, 18.3)[bc]	23.1 (21.6, 24.9)[b]	**<0.01**	**<0.01**

BMI: Body Mass Index (kg/m²)
WHR: Waist to Hip Ratio
WtHR: Weight to Height Ratio
High BF%: ≥35%, Normal BF% <35%
Obesity: BMI ≥30, *Overweight:* BMI≥25<30, *Normal BMI:* BMI ≥18.5-≤24.9
Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance

a-c: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05. within Pacific for BMI comparisons
d-f: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05. within Pacific for BMI comparisons
g-h: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05 between ethnicities

a-b values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05 within ethnicities for BF% comparisons
c-d: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05 between ethnicities for BF% comparisons
^Statistical significance within ethnicity
**Statistical significance between ethnicities*

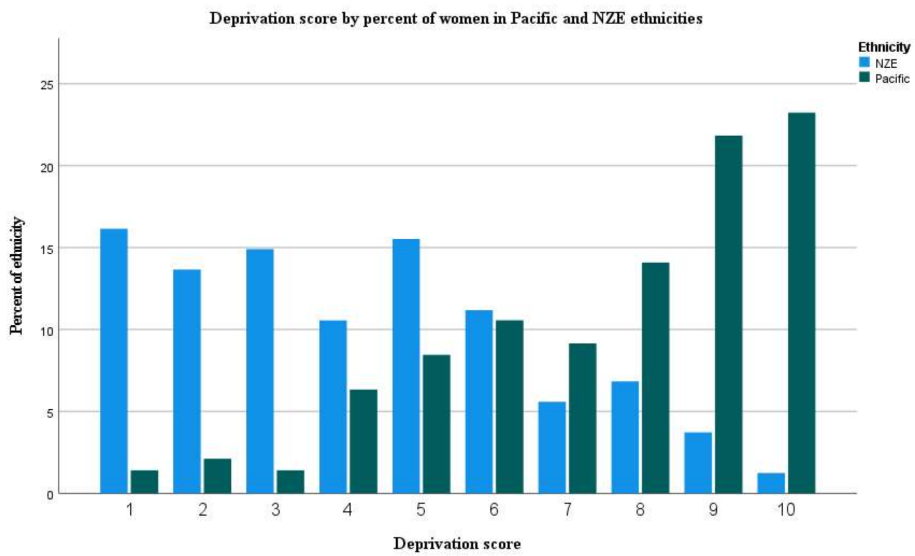

Figure 3.1: Deprivation score by ethnicity

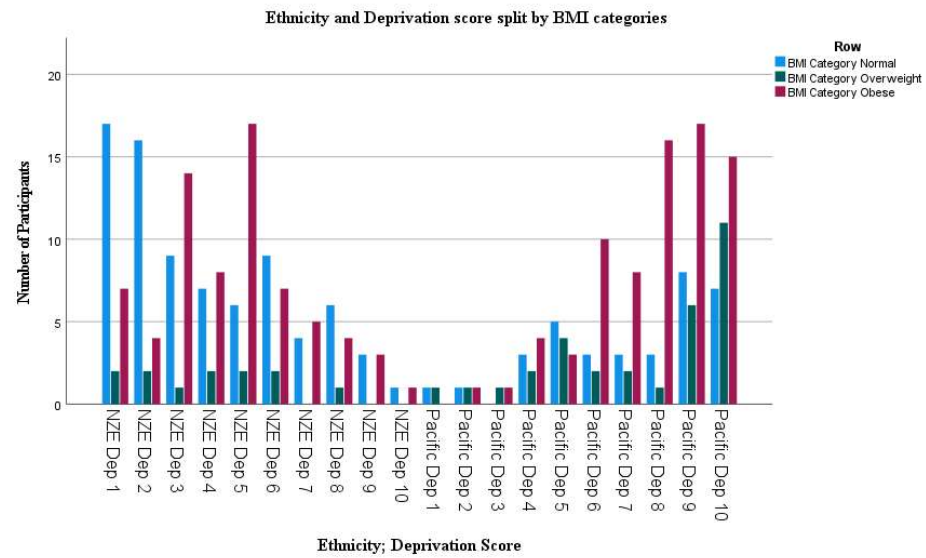

Figure 3.2: Deprivation score by ethnicity and BMI

Intake of fruit and vegetable servings

Within each ethnicity, there were no significant differences across BMI categories for combined daily fruits and vegetable serves, fruit, or vegetable servings for Pacific women, whilst for NZE it differed significantly between obese and overweight categories (Table 3.2).

Between ethnicities, there was a significant difference in combined daily fruit and vegetable serves for normal BMI (Pacific: 3.24 (2.33, 4.26) versus NZE: 4.70 (3.71, 6.35). In the obese category, NZE ate significantly more servings of vegetables (2.81 (1.77, 3.93) than Pacific women (1.92 (1.35, 3.27). In both BF% groups, NZE consumed significantly more daily and vegetable serves than Pacific.

Nearly all normal (98.7%) and obese (97.2%) BMI Pacific women did not consume the recommended five servings of vegetables as less than 3% of both BMI groups met the recommendations. Significantly less obese than normal BMI NZE women consumed five servings of vegetables (P=0.04). Less than 30% of Pacific women consumed two or more fruit serves per day. This was similar to NZE as less than 20% of obese and normal BMI women consumed five servings of vegetables and less than 40% consumed two servings of fruit.

Table 3.2: Intake of Fruit, Vegetable, and combined servings between ethnicity and BMI category

	BMI; Pacific N=142				**BMI; NZE N=161**				
	Obese n=75(24.8%) median (25-75)	**Overweight n=31(10%)** median (25-75)	**Normal BMI n=36(11.9%)** median (25-75)	**p-value^**	**Obese n=71(23.4%)** median (25-75)	**Overweight n=12(3.9%)** median (25-75)	**Normal BMI n=78(25.7%)** median (25-75)	**p-value^**	**p-value^**
Daily serves	3.37 (2.47, 4.70)	3.80 (1.84, 4.29)	3.24 (2.33, 4.26)^{h}	0.99	4.08 (2.69, 5.16)^{d}	3.80 (2.73, 9.45)^{d}	4.70 (3.71, 6.35)^{h}	0.04	**<0.01**
Fruit	1.25 (0.55, 2.17)	1.07 (0.25, 1.97)	1.21 (0.53, 2.27)	0.65	0.94 (0.53, 2.26)	0.89 (0.61, 1.89)	1.54 (0.71, 2.64)	0.13	0.29
Vegetables	1.92 (1.35, 3.27)^{g}	2.22 (1.64, 2.94)	1.87 (1.11, 3.39)	0.70	2.81 (1.77, 3.93)^{dg}	3.59 (1.87, 5.58)^{d}	3.23 (2.37, 4.68)	0.12	**<0.01**
	Obese n=75(24.8%) n (%)	**Overweight n=31(0.1%)** n (%)	**Normal BMI n=36(11.9%)** n (%)		**Obese n=71(23.4%)** n (%)	**Overweight n=12(3.9%)** n (%)	**Normal BMI n=78(25.7%)** n (%)		
<5 serves of vegetables	74 (98.7%)	28 (90.3%)	35 (97.2%)		65 (91.5%)	8 (66.7%)	63 (80.8%)		
≥5 serves of vegetables	1 (1.3%)	3 (9.7%)	1 (2.8%)		6 (8.5%)	4 (33.3%)	15 (19.2%)		
p-value†		0.10					0.04		
p-value††									<0.01
<Two serves of fruit	53 (70.7%)	26 (83.9%)	26 (72.2%)		53 (74.6%)	9 (75.0%)	48 (61.5%)		
≥Two serves of fruit	22 (29.3%)	5 (16.1%)	10 (27.8%)		18 (25.4%)	3 (25.0%)	30 (38.5%)		
p-value†		0.36					0.20		
p-value††									0.26

	BODY FAT PERCENTAGE						
	Pacific; N=141			**NZE: N=161**			
	Normal BF% N=56	**High BF% N=85**	**P-Value***	**Normal BF% N=66**	**High BF% N=95**	**P-value***	**P-value^**
Daily serves	3.74 (2.43, 4.28)^{c}	3.33 (2.44, 4.37)^{d}	0.82	4.65 (3.55, 7.30)^{bc}	4.11 (2.80, 5.16)^{bd}	**<0.01**	**<0.01**

Fruit serves	1.29 (0.43, 1.98)	1.09 (0.54, 2.11)	0.90	1.53 (0.76, 2.64)	0.93 (0.53, 2.06)	0.05	0.17
Vegetable serves	1.96 (1.18, 3.02)[c]	1.92 (1.36, 3.27)[d]	0.64	3.24 (2.30, 4.84)[bc]	2.82 (1.79, 3.93)[bd]	**0.02**	**<0.01**
		Pacific; N=141			**NZE; N=161**		
	Normal BF% N=56	**High BF% N=85**		**Normal BF% N=87**	**High BF% N=74**		
<5 serves of vegetables	53 (94.6%)	83 (97.6%)		68 (78.2%)	68 (97.6%)		
≥5 serves of vegetables	3 (3.8%)	2 (2.4%)		19 (21.8%)	6 (8.1%)		
p-value† within ethnicites		P = 0.35			P = 0.01		
p-value†† between ethnicities							**P = <0.01**
<Two serves of fruit	43 (76.8%)	62 (72.9%)		55 (63.2%)	62 (72.9%)		
≥Two serves of fruit	13 (23.2%)	23 (27.1%)		32 (36.8%)	23 (27.1%)		
p-value† within ethnicities		0.61			0.13		
p-value†† between ethnicities							**P = 0.26**
		Pacific N=142			**NZE N=161**		
<5 serves of vegetables		105 (73.9%)			136 (84.5%)		
≥5 serves of vegetables		37 (26.1%)			25 (15.5%)		

p-value†† between ethnicties		P <0.01
<Two serves of fruit	104 (73.2%)	78 (48.4%)
≥Two serves of fruit	38 (26.8%)	83 (51.6%)
p-value†† between ethnicities		P = 0.28

^Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance

**Significance tested with Mann-Whittney U test; P<0.05 denotes statistical significance*

† Significance tested with Chi-square test; P<0.05 denotes statistical significance within ethnicities between BMI categories

†† Significance tested with Chi-square test; P<0.05 denotes statistical significance between ethnicities

High BF%: ≥35%, Normal BF% <35%

a-h: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05.

Obesity: BMI ≥30

Overweight: BMI≥25<30

Normal BMI: BMI ≥18.5-≤24.9

Normal BF% = <35%, High BF% = ≥35%

Considering the mean intake of the 5d-FRs, no group consumed an entire serve from one fruit and vegetable category in one day (Supplementary Table 5). More servings of green and yellow vitamin-A-rich vegetables, other non-starchy vegetables, vegetables containing some starch and Tomatoes were consumed by NZE than Pacific women in both obese and normal BMI groups. However, Pacific women consumed more starchy vegetables across the same BMI groups. NZE women with a normal BMI, consumed more servings of cruciferous (0.46 (0.14, 0.98); P<0.01)and yellow-vitamin-A-rich vegetables (0.47 (0.13, 0.85); P<0.01) than those with an obese BMI (0.15 (0.00, 0.54) and 0.29 (0.07, 0.55), respectively).

Correlations of fruit and vegetable intake and body composition

Combined daily serves of fruit or vegetables were inversely correlated with BMI (-0.15), BF% (-0.21), WC (-0.19), sagittal height (-0.15), WHR (-0.17), and WHtR (-0.14) controlling for age and ethnicity (Table 3.3). Vegetables were inversely correlated with BMI (-0.16), BF% (-0.20), WC (-0.19), sagittal height (-0.16), WHR (-0.16) and WHtR (-0.15). Inverse correlations with BMI and BF% were found for cruciferous vegetables (-0.13, -0.18), green (-0.14, -0.18) and yellow (-0.12, -0.14) vitamin-A-rich-vegetables, non-starchy vegetables (-0.13, -0.17), and total fibre intake (-0.15. -0.22).

Table 3.3: Correlation between servings and body composition measurements controlling for age and ethnicity

	BMI		BF%		WC		Sagittal Height		VF%		WHR		WHtR	
Category	*Spearmans rho*	*p-value*	*Spearmans rho*	*p-value*	*Spearmans rho*	*p-value*	*Spearmans rho*	*p – value*	*Spearmans rho*	*p-value*	*Spearmans rho*	*p-value*	*Spearmans rho*	*p-value*
Daily serves	**-0.15**	<0.01	**-0.21**	<0.01	**-0.19**	<0.01	**-0.15**	0.01	-0.07	0.24	**-0.17**	<0.01	**-0.14**	0.01
Fruit serves	-0.06	0.27	-0.12	0.06	-0.09	0.10	-0.06	0.27	-0.05	0.43	-0.11	0.07	-0.06	0.29
Vegetable serves	**-0.16**	<0.01	**-0.20**	<0.01	**-0.19**	<0.01	**-0.16**	<0.01	-0.05	0.36	**-0.16**	<0.01	**-0.15**	<0.01
Citrus fruits	-0.09	0.11	-0.07	0.21	-0.08	0.16	-0.05	0.35	0.02	0.72	-0.04	0.48	-0.09	0.12
Vitamin A rich fruit	0.02	0.77	-0.01	0.90	-0.01	0.99	-0.01	0.96	-0.01	0.94	-0.02	0.78	0.02	0.76
Berries	-0.01	0.87	-0.09	0.12	-0.1	0.86	-0.03	0.66	-0.05	0.37	0.01	0.95	-0.01	0.94
Other fruits	-0.04	0.49	-0.09	0.11	-0.08	0.16	-0.05	0.39	-0.07	0.25	**-0.12**	0.04	-0.04	0.52
Allium vegetables	0.01	0.89	-0.08	0.16	-0.01	0.91	0.01	0.96	-0.05	0.35	-0.03	0.57	0.03	0.62
Cruciferous vegetables	**-0.13**	0.03	**-0.18**	<0.01	**-0.16**	<0.01	**-0.15**	0.01	-0.03	0.56	**-0.14**	0.01	**-0.13**	0.03
Green vitamin A rich vegetables	**-0.14**	0.02	**-0.18**	<0.01	**-0.16**	0.01	**-0.12**	0.04	-0.08	0.15	**-0.12**	0.04	**-0.13**	0.02
Yellow vitamin A rich vegetables	**-0.12**	0.04	**-0.14**	0.02	**-0.13**	0.03	**-0.12**	0.04	-0.02	0.77	-0.05	0.36	**-0.12**	0.04
Other non-starchy vegetables	**-0.13**	0.02	**-0.17**	<0.01	**-0.14**	0.01	**-0.13**	0.02	-0.11	0.05	-0.10	0.07	**-0.12**	0.04
Starchy vegetables	0.06	0.28	0.09	0.12	0.06	0.31	0.08	0.17	0.04	0.50	0.03	0.58	0.06	0.29

Category	BMI Spearmans rho	BMI p-value	BF% Spearmans rho	BF% p-value	WC Spearmans rho	WC p-value	Sagittal Height Spearmans rho	Sagittal Height p – value	VF% Spearmans rho	VF% p-value	WHR Spearmans rho	WHR p-value	WHtR Spearmans rho	WHtR p-value
Vegetables containing starch	-0.06	0.32	-0.05	0.40	-0.06	0.31	-0.09	0.11	0.03	0.64	-0.05	0.43	-0.06	0.34
Tomatoes	-0.01	0.91	-0.01	0.94	-0.03	0.58	-0.01	0.99	0.10	0.09	-0.11	0.05	<0.01	0.99
Total fibre	**-0.15**	0.01	**-0.22**	<0.01	**-0.15**	0.01	**-0.13**	0.02	**0.01**	0.97	-0.11	0.05	**-0.13**	0.03

Correlations tested with spearmans correlation coefficient. Significance at P<0.05.
BMI: Body Mass Index
BF%: Body fat percentage
WC: Waist circumference
VF%: Visceral fat percentage
WHR: Waist-to-Hip ratio
WHtR: Weight-to-height ratio

The linear regression (Table 3.4) reveals that age, ethnicity, deprivation and vegetable servings are significant predictors of BMI and BF% although fruit servings are not. When accounting for age, ethnicity and deprivation (Model 2a), vegetable servings account for 15% of BMI scores. For every one increase in vegetable servings (75g) BMI reduces by 0.65kg/m^2 (P <0.01). When accounting for age, ethnicity and deprivation (Model 2b), vegetable servings account for 12% of BF%. For every one increase in vegetable servings (75g), BF% reduces by 1.16 percent. The addition of fruit serves to these models (Model 3a, 3b), does not explain more of the variance.

When separate by ethnicity (Appendix B: Other results table 5 and 6), age, deprivation and vegetable servings were still significant predictors of reduction in BMI and BF%, however only for NZE women, with vegetable servings (-0.83lg/m^2 and -1.40%) being even a stronger predictor. Although vegetable serves were still predicting BMI and BF% in Pacific women, it was no longer significant.

Table 3.4: Linear Regression of servings and BMI and BF%

Model for BMI		β	Std error β	95% Cl β	Std'ised β	P-value*
1a	Age	0.25	0.06	0.13, 0.36	0.26	<0.01
	Ethnicity	3.46	0.98	1.54, 5.38	0.25	<0.01
	Deprivation	0.49	0.16	0.16, 0.81	0.20	<0.01
			F ratio: 15.1 (3 296) adjusted r^2 0.12 P<0.01			
2a	Age	0.26	0.06	0.15, 0.38	0.28	<0.01
	Ethnicity	2.86	0.99	0.92, 4.80	0.20	<0.01
	Deprivation	0.48	0.16	0.16, 0.80	0.20	<0.01
	Vegetable serves	-0.65	0.23	-1.10, -0.21	-0.16	<0.01
			F ratio 13.7 (4 295) adjusted r^2 0.15 P <0.01			
3a	Age	0.26	0.06	0.15, 0.37	0.28	<0.01
	Ethnicity	2.84	0.99	0.90, 4.79	0.20	<0.01
	Deprivation	0.49	0.16	0.17, 0.81	0.20	<0.01
	Vegetable Serves	-0.61	0.23	-1.07, -0.15	-0.15	<0.01
	Fruit Serves	-0.21	0.3-	-0.79, 0.37	-0.04	0.48
			F ratio 11.0 (5 294) adjusted r^2 0.14 P <0.01			

Model for BF%		β	Std error β	95% Cl β	Std'ised β	P-value*
1b	Age	0.32	0.08	0.16, 0.48	0.24	<0.01
	Ethnicity	3.54	1.40	0.80, 6.29	0.18	<0.01
	Deprivation	0.65	0.24	0.18, 1.11	0.19	<0.01
			F ratio 10.4 (3 295) adjusted r^2 0.09 P <0.01			
2b	Age	0.35	0.08	0.19, 0.51	0.26	<0.01
	Ethnicity	2.47	1.40	-0.29, 5.29	-0.13	0.08
	Deprivation	0.64	0.23	0.19, 1.09	0.19	<0.01
	Vegetable Serves	-1.16	0.32	-1.79, -0.53	-0.21	<0.01
			F ratio 11.3 (4 294) adjusted r^2 0.12 P <0.01			
3b	Age	0.35	0.08	0.19, 0.51	0.26	<0.01

Model for BF%		β	Std error β	95% Cl β	Std'ised β	P-value*
	Ethnicity	2.44	1.40	-0.31, 5.20	0.12	0.08
	Deprivation	0.66	0.23	0.20, 1.11	0.19	<0.01
	Vegetable Serves	-1.06	0.33	-1.71, -0.41	-0.19	<0.01
	Fruit Serves	-0.53	0.42	-1.35, 0.30	-0.07	0.21
			F ratio 9.41 (5 293) adjusted r^2 0.12 P <0.01			

BF%: body fat percentage

BMI: Body Mass Index

**Significance at <0.05*

Ethnicity refers to NZE and ethnicity

Deprivation scores range from 1-10 based on NZDep2013

Between mealtimes, consumption of fruits and vegetable servings was highest at the dinner period for all groups excluding Pacific overweight BMI (Supplementary results).

Between ethnicities, total servings at dinner were higher in NZE women with an obese BMI (1.63 (1.17, 2.42) than Pacific women with an obese BMI (0.77 (0.20, 1.89) and higher in NZE with a normal BMI (0.92 (0.37, 1.72) than Pacific women with a normal BMI (1.94 (1.35, 2.96) ($P<0.01$).

Pacific with an obese BMI consumed significantly less servings than NZE at breakfast (Pacific=0.00(0.00, 0.38) versus NZE=0.46(0.03, 0.93); $P<0.01$), lunch (Pacific=0.29(0.00, 0.73) versus NZE=0.69(0.40, 1.44); $P<0.01$) and dinner (Pacific=0.77(0.20, 1.89) versus NZE=1.63(1.17, 2.42); $P <0.01$) but consumed more at supper (Pacific=0.00(0.00, 0.66) versus NZE=0.00(0.00, 0.00); $P<0.01$).

In NZE women, breakfast, lunch and dinner contributed the highest serves of fruits or vegetables in both obese and normal BMI groups ($P<0.01$). In Pacific women, lunch, afternoon tea, and dinner provided the most serves ($P<0.01$).

Nutrient analysis

No differences in total energy intake and percentage of energy from fruit and vegetables between BMI or ethnicity were found.

Within NZE only, those with an obese BMI consumed less total fibre (20.9 (17.3, 25.5) and dietary fibre from fruit and vegetables only (7.28 (5.35, 10.83) than those with a normal BMI ((23.8 (19.7, 30.4); 9.10 (6.41, 11.39) respectively).

Between ethnicities, carbohydrates from fruit and vegetables were higher for obese Pacific (46.8 (29.9, 66.1)) than obese NZE women (36.8 (24.8, 50.9). Similarly, the percentage of sugar from fruit and vegetables was higher for Pacific women with an obese BMI (7.60 (5.29, 12.3) than NZE (4.54 (3.20, 6.15). Fat from fruits and vegetables was higher in Pacific women with a normal BMI (9.92 (7.19, 16.2)) than NZE (6.15 (3.84, 11.5)). Pacific women had less total dietary fibre intake than NZE in both obese (17.4 (13.9, 21.2) versus (20.9 (17.3, 25.5)) and normal BMI 17.9 (14.3, 21.1) versus 23.8 (19.7, 30.4) groups. No significant difference was seen in percentage of dietary fibre from fruit and vegetables to the total intake and no difference in soluble fibre intakes.

Within ethnicities, total carbohydrate, total sugar and carbohydrate and sugars from fruit and vegetables were higher in those with a lower BF% than high BF%. Total dietary fibre intake and dietary fibre intake from fruit and vegetables only was higher in those with a normal BF% (24.0 (19.5, 30.4) and (9.08 (6.25, 12.0) respectively) compared to those with a higher BF% (20.9 (17.3, 25.4) and 7.30 (5.27, 10.7) respectively) in NZE only.

Between ethnicities, energy intake (kJ) from fruit and vegetables in those with a normal BF% was higher in Pacific (1509 (1029, 2049)) than NZE (1180 (907, 1570)). The percentage of fat from fruit and vegetables to the total intake in those with a normal BF% was higher in Pacific than NZE women. Total carbohydrate, and carbohydrate and sugars from fruit and vegetables were higher in Pacific than NZE in both normal BF% and high BF%.

Between ethnicities, Pacific women with a normal BF% consumed less total fibre (18.7 (15.2, 23.9)) and had a lower percentage of fibre from fruits and vegetables (7.06 (5.01, 10.6)) than NZE with a normal BF% (24.0 (19.5, 30.4); 9.08 (6.25, 12.0) respectively). Total insoluble fibre was higher in those with a normal BF% than those with a high BF% in NZE women only.

Table 3.6: Nutrient intake from fruit and vegetables and total food separated by ethnicity and BMI category

Nutrient		Pacific=142 Obese n=75(24.8%) median (25-75)	Overweight n=31(10%) median (25-75)	Normal BMI n=36(11.9%) median (25-75)	p-value^	BMI; NZE = 161 Obese n=71(23.4%) median (25-75)	Overweight n=12(3.9%) median (25-75)	Normal BMI n=78(25.7%) median (25-75)	p-value^	p-value*
Weight (g)	*Fruit and vegetables only*	305 (245, 436)	388 (193, 500)	310 (217, 453)	0.51	346 (226, 459)[d]	270 (236, 571)	416 (340, 541)[d]	**0.01**	**<0.01**
	Total Food	2187 (1815, 2743)[g]	2301 (1838, 2907)	2082 (1536, 2616)	0.50	2564 (2063, 3226)[g]	2647 (2275, 3995)	2755 (2209, 3583)	0.29	**<0.01**
	%	13.2 (10.6, 18.3)	15.3 (10.6, 19.6)	15.7 (10.1, 20.7)	0.64	13.7 (8.68, 16.7)	12.9 (7.99, 19.0)	14.7 (11.5, 20.2)	0.14	0.39
Energy (kj)	*Fruit and vegetables only*	1299 (909, 1831)	1625 (963, 2603)[a]	1373 (1058, 2009)	0.22	1207 (741, 1492)	968 (704, 1455)[a]	1194 (907, 1572)	0.39	**0.03**
	Total Food	8694 (6667, 10217)	9657 (7146, 11799)	8846 (7520, 9717)	0.22	8423 (7106, 9534.)	8951 (7945, 9344)	8101 (7005, 9351)	0.50	0.21
	%	15.7 (12.0, 21.3)	17.5 (10.3, 26.0)	16.7 (11.5, 21.5)	0.67	13.7 (9.88, 19.1)	10.5 (8.08, 15.2)	15.3 (11.7, 19.2)	0.15	0.12
Protein (g)	*Fruit and vegetables only*	6.32 (4.12, 10.1)[g]	9.38 (5.40, 14.5)	6.91 (4.19, 12.0)[h]	0.24	8.01 (5.33, 13.5)[g]	8.55 (4.89, 11.0)	9.41 (6.27, 13.7)[h]	0.40	**0.02**
	Total Food	82.6 (67.2, 107)	88.4 (69.7, 103)	75.5 (65.7, 95.1)	0.51	89.3 (72.7, 99.2)	85.9 (83.8, 98.0)	82.6 (73.6, 96.1)	0.25	0.48
	%	8.68 (5.02, 12.6)	12.1 (5.94, 17.6)	8.55 (5.64, 14.0)[h]	0.32	9.81 (5.82, 16.6)	9.84 (5.61, 12.3)	12.3 (6.94, 18.0)[h]	0.18	**0.02**
Carbohydrate (g)	*Fruit and vegetables only*	46.8 (29.9, 66.1)[g]	58.9 (31.3, 84.7)	48.2 (33.2, 62.7)	0.42	36.8 (24.8, 50.9)[g]	34.3 (20.9, 46.0)	38.3 (28.8, 53.0)	0.41	**<0.01**
	Total Food	222 (155, 255)[g]	249 (194, 318)	217 (164, 252)[h]	0.28	185 (152, 230)[g]	177 (122, 251)	182 (151, 208)[h]	0.80	**<0.01**
	%	23.3 (16.2, 30.1)	25.9 (13.8, 32.1)	22.7 (15.3, 30.9)	0.99	21.0 (12.7, 28.9)	17.2 (12.3, 29.7)	22.9 (15.6, 29.9)	0.32	0.72
Sugars (g)	*Fruit and vegetables only*	6.38 (3.83, 9.15)[g]	4.75 (3.14, 6.89)	6.26 (3.97, 8.38)[h]	0.11	4.54 (3.20, 6.15)[g]	3.99 (3.17, 6.53)[a]	4.82 (3.28, 6.27)[h]	0.87	**<0.01**
	Total Food	78.0 (57.3, 110)	84.6 (72.0, 129)	88.0 (77.2, 111.3)	0.54	76.0 (62.1, 99.9)	93.4 (75.6, 112)	77.4 (55.9, 93.8)	0.20	0.16
	%	7.60 (5.29, 12.3)[g]	5.68 (3.33, 9.02)	7.00 (4.22, 11.0)	0.08	5.51 (3.98, 8.58)[g]	4.71 (3.76, 5.82)	6.65 (5.04, 8.07)	0.06	**<0.01**

Starch (g)	*Fruit and Vegetables only*	19.5 (9.81, 29.3)	23.3 (8.53, 38.2)	21.1 (14.8, 30.7)	0.54	15.5 (8.97, 23.7)de	35.5 (15.0, 50.8)e	22.0 (12.1, 36.0)d	**0.02**	0.08
	Total Food	108 (84.1, 140)	120 (81.0, 133)	125 (93.6, 159)	0.39	106 (81.9, 141) d	144 (117, 176.) de	111 (88.8, 141)e	**0.01**	0.06
	%	19.2 (9.78, 27.2)	21.6 (7.49, 31.0)	17.3 (13.4, 23.4)	0.86	14.8 (8.10, 27.3)	21.9 (11.9, 28.0)	19.6 (12.6, 29.3)	0.07	0.35
Total fat (g)	*Fruit and vegetables only*	8.59 (4.30, 15.2)[a]	14.0 (6.13, 19.1)[a]	9.92 (7.19, 16.2)[h]	0.06	7.18 (3.65, 13.2)	5.60 (3.30, 7.79)	6.15 (3.84, 11.5)[h]	0.61	**<0.01**
	Total Food	86.6 (59.4, 109)	106 (75.6, 119)	94.2 (81.1, 108)	0.10	87.3 (71.9, 113)	92.7 (81.5, 115)	84.8 (68.3, 107)	0.46	0.25
	%	10.9 (5.40, 15.2)[g]	14.7 (6.65, 20.2)[b]	11.5 (6.79, 19.7)[bh]	0.15	8.46 (4.83, 14.6)[g]	6.38 (4.52, 7.66)	7.19 (4.67, 14.8)[h]	0.45	**0.01**
Dietary fibre (g)	*Fruit and vegetables only*	6.62 (4.93, 9.22)	8.94 (4.72, 11.3)	6.71 (5.01, 9.96)[h]	0.32	7.28 (5.35, 10.83)[d]	6.42 (5.00, 12.05)	9.10 (6.41, 11.39)[dh]	**0.04**	**<0.01**
	Total Food	17.4 (13.9, 21.2)[ag]	21.3 (15.9, 26.0)[a]	17.9 (14.3, 21.1)[h]	0.05	20.9 (17.3, 25.5)[dg]	22.5 (16.6, 28.2)	23.8 (19.7, 30.4)[dh]	**0.04**	**<0.01**
	%	39.0 (30.5, 51.2)	40.2 (26.6, 51.4)	41.1 (28.9, 50.7)	0.89	35.6 (25.8, 43.7)	41.1 (31.2, 47.9)	38.1 (28.4, 47.7)	0.47	0.56
Soluble fibre (g)	*Fruit and vegetables only*	1.51 (0.83, 2.26)	1.39 (0.59, 2.81)	1.16 (0.69, 2.66)	0.70	1.06 (0.63, 1.67)	0.92 (0.75, 1.77)	1.22 (0.61, 1.76)	0.95	0.15
	Total Food	3.06 (2.24, 5.02)	3.72 (2.69, 6.18)	3.02 (2.17, 4.09)	0.07	2.90 (2.12, 3.97)	3.41 (1.38, 3.95)	2.99 (2.00, 4.12)	0.97	0.10
	%	49.8 (30.7, 69.6)	41.5 (21.8, 60.7)	49.9 (25.6, 72.2)	0.45	39.6 (26.9, 56.3)	47.8 (24.5, 60.3)	46.4 (26.8, 55.7)	0.79	0.19
Insoluble fibre (g)	*Fruit and vegetables only*	1.37 (0.84, 2.20)	1.60 (0.80, 2.09)	1.26 (0.63, 2.29)	0.69	1.37 (0.75, 1.94)	1.57 (0.84, 2.17)	1.57 (0.89, 2.54)	0.27	0.65
	Total Food	3.59 (2.22, 5.14)	3.34 (3.09, 4.74)	2.90 (2.30, 4.63)[h]	0.23	3.39 (2.48, 5.46)	3.35 (2.46, 5.67)	4.23 (3.26, 5.73)[h]	0.18	**0.02**
	%	50.8 (31.8, 68.0)[g]	48.5 (24.7, 56.8)	49.7 (29.9, 69.7)[h]	0.37	38.8 (21.3, 52.9)[g]	50.3 (26.0, 61.5)	43.2 (24.4, 55.5)[h]	0.40	**0.04**

Percentage: calculated by dividing fruit and vegetable only by total for each participant and average for new variable.
Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance
a-h: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05.
^within ethnicity
**between ethnicities*
Obesity: BMI ≥30
Overweight: BMI≥25<30
Normal BMI: BMI ≥18.5-≤24.9

Table 3.7: Nutrient intake from Fruit and Vegetables and Total Food by ethnicity and BF%

Nutrient		Pacific=141 BF% <35 median (25-75)	Pacific=141 BF% ≥35 median (25-75)	p-value^	NZE=161 BF% <35 median (25-75)	NZE=161 BF% ≥35 median (25-75)	p-value^	p-value*
Weight (g)	*Fruit and vegetables only*	359 (219, 470)	310 (240, 429)	0.41	408 (329, 545)[a]	350 (232, 459)[a]	**<0.01**	**<0.01**
	Total Food	2178 (1650, 2926)[ac]	2192 (1882, 2742)[ad]	0.65	2852 (2290, 3703)[bc]	2561 (2059, 3122)[bd]	**0.03**	**<0.01**
	Percentage of Total	15.2 (10.5, 20.7)	13.7 (10.6, 19.3)	0.43	14.37 (11.27, 2010)	13.97 (9.31, 16.82)	0.25	0.51
Energy (kj)	*Fruit and vegetables only*	1509 (1029, 2049)[c]	1314.26 (931.35, 1925.51)	0.30	1180 (907, 1570)[c]	1189 (742, 196)	0.42	**0.02**
	Total Food	8963 (7174, 10384)	8731 (6869, 10231)	0.45	8167 (7083, 9427)	8342 (7078, 9395)	0.94	0.26
	%	17.0 (11.3, 22.4)	15.8 (12.3, 21.3)	0.58	15.0 (11.0, 18.8)	13.7 (9.88, 19.1)	0.71	0.18
Protein (g)	*Fruit and vegetables only*	7.35 (4.63, 12.3)	9.59 (4.10, 10.5)	0.30	8.86 (5.92, 13.4)	8.32 (5.36, 13.6)	0.68	0.79
	Total Food	80.7 (66.2, 99.7)	82.6 (68.6, 107)	0.67	84.0 (73.9, 99.2)	88.9 (74.0, 97.3)	0.51	0.79
	%	9.24 (5.64, 14.4)	8.73 (5.31, 12.9)[d]	0.34	11.01 (6.51, 17.10)	10.9 (6.04, 16.8)[d]	0.60	**0.03**
Carbohydrate (g)	*Fruit and vegetables only*	51.4 (32.7, 68.4)[ac]	46.8 (30.2, 65.7)[ad]	0.36	39.1 (28.8, 52.7)[bc]	36.1 (23.9, 50.9)[bd]	0.26	**<0.01**
	Total Food	217 (174, 273)[bd]	222 (161, 264)[ac]	0.73	182 (146, 213)[ab]	182 (151, 230)[cd]	0.56	**<0.01**
	%	23.1 (15.3, 30.9)	22.7 (16.0, 28.9)	0.71	22.6 (15.6, 29.9)	21.0 (12.7, 28.9)	0.24	0.58

Nutrient		Pacific=141 BF% <35 median (25-75)	BF% ≥35 median (25-75)	p-value^	NZE=161 BF% <35 median (25-75)	BF% ≥35 median (25-75)	p-value^	p-value*
Sugars (g)	*Fruit and vegetables only*	6.04 (4.02, 8.43)[bd]	5.94 (3.60, 8.24)[ac]	0.95	4.58 (3.21, 6.27)[cd]	4.57 (3.29, 6.23)[ab]	0.97	**<0.01**
	Total Food	86.1 (71.8, 116)	85.5 (58.8, 110)	0.26	78.7 (58.3, 95.0)	76.5 (62.1, 99.9)	**0.01**	0.14
	%	6.57 (3.94, 11.3)	6.68 (5.10, 11.0)	0.52	6.19 (4.53, 7.76)	5.62 (4.01, 8.62)	0.38	0.06
Starch (g)	*Fruit and vegetables only*	22.3 (15.3, 33.5)	18.5 (9.62, 29.3)	0.11	22.0 (12.7, 38.4)[b]	15.8 (8.97, 24.4)[b]	**0.02**	**0.04**
	Total Food	125 (92.8, 148)	107 (84.1, 140)	0.17	116 (91.2, 148)	106 (82.9, 141)	0.10	0.20
	%	19.1 (13.5, 28.9)	18.5 (9.63, 26.2)	0.51	19.8 (12.3, 29.3)	14.9 (9.15, 27.3)	**0.04**	0.19
Total fat (g)	*Fruit and vegetables only*	10.6 (6.93, 16.6)[c]	8.94 (4.44, 15.7)[d]	0.17	6.21 (3.80, 11.3)[c]	6.85 (3.65, 13.0)[d]	0.73	**<0.01**
	Total Food	95.3 (76.8, 116)	90.3 (59.4, 111)	0.17	88.2 (69.1, 111)	86.5 (72.8, 110)	0.79	**0.48**
	%	12.0 (6.45, 19.6)[c]	11.2 (5.50, 15.8)	0.39	6.91 (4.67, 14.6)[c]	8.08 (4.83, 13.8)	0.62	**0.01**
Dietary fibre (g)	*Fruit and vegetables only*	7.06 (5.01, 10.6)[c]	6.93 (4.92, 9.24)	0.46	9.08 (6.25, 12.0)[bc]	7.30 (5.27, 10.7)[b]	**0.01**	**<0.01**
	Total Food	18.7 (15.2, 23.9)[c]	18.0 (14.2, 21.6)[d]	0.34	24.0 (19.5, 30.4)[bc]	20.9 (17.3, 25.4)[bd]	**0.01**	**<0.01**
	%	40.85 (28.85, 49.71)	38.42 (30.42, 50.06)	0.93	38.43 (27.36, 47.72)	35.64 (26.12, 43.54)	0.33	0.39
Soluble fibre (g)	*Fruit and vegetables only*	1.32 (0.78, 2.94)	1.51 (0.68, 2.26)	0.75	1.23 (0.62, 1.82)	1.01 (0.63, 1.63)	0.37	0.05
	Total Food	3.37 (2.23, 4.66)	3.12 (2.28, 5.02)	0.76	3.09 (2.10, 4.12)	2.85 (2.06, 3.80)	0.45	0.22
	%	49.4 (23.7, 72.2)	48.6 (30.7, 65.2)	0.99	46.8 (26.8, 56.3)	39.6 (26.9, 56.3)	0.59	0.15
Insoluble fibre (g)	*Fruit and vegetables only*	1.40 (0.75, 2.29)	1.37 (0.68, 2.10)	0.69	1.60 (0.88, 2.54)	1.36 (0.77, 1.89)	0.06	0.31

Nutrient		Pacific=141			NZE=161			
		BF% <35 median (25-75)	**BF% ≥35** median (25-75)	**p-value^**	**BF% <35** median (25-75)	**BF% ≥35** median (25-75)	**p-value^**	**p-value***
	Total Food	3.17 (2.62, 4.67)[c]	3.59 (2.22, 5.14)	0.92	4.22 (3.21, 5.73)[bc]	3.31 (2.43, 5.29)[b]	**0.048**	**0.01**
	%	51.1 (29.8, 65.3)	48.5 (31.7, 66.6)[d]	0.90	43.4 (24.3, 55.8)	38.9 (21.9, 52.9)[d]	0.51	**0.04**

Percentage: calculated by dividing fruit and vegetable only by total for each participant and average for new variable.

Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance

a-h: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05.

High BF%: ≥35%, Normal BF% <35%

^within ethnicity

**between ethnicities*

Within Pacific, women with a normal BMI had higher sodium intake from fruits and vegetables than an obese BMI (Appendix B: Supplementary results table 2). Within NZE, women with a normal BMI had a lower sodium intake from fruit and vegetables (183 (164, 529)) than an obese BMI (279 (126, 404)). The percentage of total sodium from fruit and vegetables was higher in those with a normal BMI than an obese BMI in both Pacific and NZE.

Within ethnicities, women with an obese BMI had a lower total intake of vitamin C from fruit and vegetables only than women with a normal BMI in both Pacific and NZE. Within NZE, obese total intake and percentage of vitamin A from fruits and vegetables were significantly lower than normaly BMI but this was not seen in Pacific women.

Between ethnicities, NZE had higher folate than Pacific women in both obese (78.7 (46.1, 122) versus (66.3 (36.0, 93.7)), and normal BMI groups (96.0 (59.5, 138) versus 67.7 (41.4, 101). NZE had a higher intake of vitamin A from fruit and vegetables than Pacific women in obese and normal BMI categories. Pacific women had a lower Percentage of total iron from fruit and vegetables than NZE for an obese (14.2 (8.93, 20.4) versus 19.5 (13.1, 26.7)) and normal BMI (14.8 (11.4, 20.5) versus 18.8 (12.7, 28.6)). No significant differences in intake of magnesium, potassium, or phosphate from fruit and vegetables only were found.

Diversity of Intake and commonly consumed fruits and vegetables

Over seven days, "other fruit" was most often consumed (Pacific=93%, NZE=95%) (Appendix B: Supplementary results table 5). For both ethnicities, banana was the most popular (NZE=83.7%, Pacific=87.1%) followed by Apples (NZE=78.4%, Pacific=81.1%). Citrus fruits were commonly consumed (NZE=87.6%, Pacific=82.4%), with lemon/lime most popular in Pacific women (70%) and oranges in NZE (68.8%). Vitamin A fruits were the least consumed (Pacific=56.3% NZE=50.3%).

The cruciferous vegetable group was consumed by all participants. For Pacific, broccoli was the highest consumed (84.3%) then cabbage (50.7%) and cauliflower (45.8%). For NZE, broccoli was the highest consumed (84.2%), then cabbage (56.5%) and cauliflower (52.8%). Intake of yellow vitamin-A-rich-vegetables was second most common (NZE=96.3%, Pacific=96.5%) with carrots ranked highest (NZE=93.5% Pacific=95.6%). The most consumed vegetables amongst NZE were onions (91.9%), carrots (90.1%), tomatoes (88.2%), lettuce (85.7%) and potatoes (82.0%). For Pacific, the most common vegetables were carrots (92.3%), onion (91.5%), tomatoes (93.7%), potato (89.4%), and lettuce (81%).

Discussion

Characteristics

The PROMISE study was designed to intentionally recruit a study population of women that was equally distributed between Pacific and NZE ethnicities and with half within each ethnicity having an obese BMI and half a normal BMI. Due to the self-reported screening process, some weight and height measurements differed from actual measurements resulting in some women being classified as overweight. Around half of NZE women were of a normal BMI (48%) but only 25% of Pacific women were of a normal BMI. BF% was also significantly different between BMI categories, with those classified as obese having a significantly higher BF% than those with a normal BMI. However, when split by BF% groups, there was a more even distribution of high BF% and normal BF% within ethnicities suggesting BF% was a useful measurement of obesity alongside BMI. This is consistent with Romero-Corral et al. (2008) who found BMI to have a high specificity but poor sensitivity for BF% resulting in those with an obese BMI being categorized correctly, while those with a normal or overweight BMI potentially having a high BF%.

Within ethnicities, those with a higher BF% had a higher muscle mass than those with a normal BF%. Between ethnicities, muscle mass was significantly higher in Pacific women compared to NZE with an obese BMI, and significantly higher than NZE in both BF% categories. However, there is no reason to suggest the BMI cut-offs have misclassified healthy individuals as obese as there was no significant difference in BF% between ethnicities which were both well above the 35% threshold.

Fruit and vegetable Servings

In both ethnicities, only around a quarter of women met the recommended five servings of vegetables (Pacific=26.1%, NZE=15.5%), and two servings of fruit per day (Pacific=26.8%, NZE=51.6%) (Table 3.2). This is lower than the Ministry of Health (2020a) data which reports 28% of Pacific and 42.5% of NZE women met the previous two serves of fruit and three serves of vegetables guidelines. Pacific women consumed equally fruit and vegetables, but NZE women clearly preferred fruit over vegetables. Within the obese BMI category, nearly all of the women (Pacific= 98.7%, NZE=91.5%) did not meet the vegetable guidelines; similarly, for those with a high BF% (Pacific=97.6%, NZE=97.6%), and this was negligibly lower than those with a normal BMI and normal BF%. A large majority of women also did not meet the recommended fruit intake (Table 3.2) and was higher than reported by national survey statistics (56%) (Ministry of Health, 2020a).

No significant median differences were seen between BMI groups and differences of combined daily servings. Vegetables servings between BF% groups were significantly different in NZE women only. In both BF% groups, NZE consumed more total and vegetable serves than Pacific women however, these were both below the recommendations. These results are concerning as it reveals the majority of women, regardless of body composition or ethnicity, are not meeting the previous or the current fruit and vegetable guidelines. This is in line with the latest Ministry of Health (2020a) statistics which shows less than half of both NZE (42.5%) and Pacific (28%) met the previous fruit and vegetable guidelines.

Data from this study show total combined daily serves of fruit and vegetables are significantly, although weakly, inversely correlated with BMI, BF%, WC, sagittal height, WHR and WHtR; all key measurements related to obesity and obesity-related diseases (Goh et al., 2014). Yu et al. (2018) found a significant inverse relationship with BMI and total fruit and vegetable serves, (-0.03), vegetable serves (-0.03) and fruit serves (-0.02) in Canadian adults. Our study provides a stronger correlation of combineddaily serves (-0.15) and vegetables serves (-0.16) however no correlation of fruit serves.

The multiple linear regression reveals that for the total group, every one increase of vegetable serves, in combination with age, ethnicity, and deprivation, BMI reduced by 0.65kg/m^2 and BF% by 1.16%. These findings are higher than Yu et al. (2018), who found for each increase of 1.4 ½ cup serves of vegetables, BMI reduced by 0.05kg.m^2 in women and BF% by 0.18% when adjusted for age and province. However Yu et al. (2018) also found statistical significance of fruit intake resulting in a reduction in BMI of 0.14kg/m^2 and in BF% of 0.35% for each 1.4 ½ cup increase in fruit serves which this study did not find. An average woman in our study would achieve a reduction of 1.87 kg for every 75 g increase in vegetable intake. This is higher than Wilunda et al. (2020) who found only a 21 g reduction in weight over five years for every 100g of vegetables consumed for a mean BMI of 23.3kg/m^2. It is also higher than Bertoia et al. (2015) who found a 0.11kg weight loss for an increase of one serving of vegetables over four years when all BMI categories were included. These results are however not consistent within the different ethnicities, being more pronounced in NZE women and not significant in Pacific women. We can speculate that Pacific women may simply not consume enough vegetables and/or total diet or lifestyle factors not explored in the current study, such as genetic regulation of metabolism, physical activity and sleep cycles (Martinez et al, 2008), may have a further impact. This needs to be further explored in future studies.

Cruciferous vegetables and yellow vitamin-A-rich vegetables were the most commonly consumed groups by both ethnicities according to the 7-day DDQ. Cruciferous vegetables, green and yellow vitamin-A-rich-vegetables, and other non-starchy vegetables were significantly inversely correlated with BMI, BF% and WC. This is similar to Wilunda et al. (2020) who found a significant inverse correlation between body weight and yellow/red vegetable intake and Liu et al (2004) who found an inverse correlation between BMI and dark yellow vegetables along with Bertoia et al. (2015) who found significant correlation between weight and cruciferous intake. The DDQ shows a similar percentage of NZE and Pacific women consumed from the vitamin-A-rich vegetables group however NZE consumed more servings of green and yellow vitamin-A-rich vegetables than Pacific women. Data from the 5d-FR found differences in intake between obese and normal BMI women existed for cruciferous vegetables (Obese=0.15(0.00, 0.54), Normal=0.46(0.14, 0.98) and yellow vitamin A-rich-vegetables (Obese=0.29(0.07, 0.55) Normal=0.47(0.13, 0.85), however in NZE women only. However, women in this study did not consume an entire fruit (150g) or vegetable (75g) serve from any one category on an average day. Therefore, it is possible that increasing serving quantity, particularly cruciferous and vitamin-A-rich vegetables could promote weight loss in Auckland women.

Pacific women consumed more servings of starchy vegetables than NZE. This study did not find a correlation with body composition however, Nour et al. (2018) found an association with intake of starchy vegetables with increased BMI. Mozaffarian et al. (2010) found each increasing serve of potato to result in 0.69 kg weight gain over four years using the Nurses' Health Study data and 0.76 kg in four years using the Nurses' Health study two data. This is supported by WHO guidelines which promote only non-starchy vegetables to reduce obesity (World Health Organization, 2002). When analysing fruit and vegetable intake by type (supplementary results Table 3), the higher intake of green and yellow vitamin-A-rich, other non-starchy vegetables, tomatoes and vegetables containing some starch by NZE compared to Pacific women reveals a higher diversity of intake. This has been associated with better regulation of hunger and satiety, a range of phytochemicals, and a more diverse gut microbiota found in non-obese individuals (Cui et al., 2019, Gonzalez-Castejon and Rodriguez-Casado, 2011). Therefore, the differences in choice of vegetable type between ethnicities in this study may have had some influence on the differences in body composition seen between ethnicities (supplementary results table 3). However, overall, the DDQ reveals low diversity within each fruit or vegetable group.

The most commonly consumed vegetables for both ethnicities were carrots, onions, lettuce, tomatoes and potatoes. It is possible promoting vegetable intake will lead to these vegetables increasing further. Increasing intake of potato, and other starchy vegetables, may have undesirable effects in increasing overall energy intake and increasing risk of obesity (Tohill, 2005). Instead, increasing frequency and serving size of cruciferous and vitamin-A-rich vegetables such as red and green cabbage, spinach, courgette, pumpkin, and capsicum, which the DDQ showed to be consumed by fewer women, may aid in reducing BMI.

Meal times

No significant differences in the intake of fruit or vegetable servings were seen at any mealtime between those with obese BMI and those with a normal BMI in either ethnicity. This is an interesting finding as it has been theorized that a higher percentage of fruits or vegetables in a meal could lead to overall lower calorie intake at a meal and therefore may relate to BMI (Dreher and Ford, 2020, Wilunda et al., 2020). Blatt et al. (2011) found hiding vegetables in meals led to reduced energy intake however the impact on body composition was not analysed. In this study, it is unknown whether fruits or vegetables were replacing foods in an overall meal or whether the fruits or vegetables was in addition to an overall meal. It may be the proportion of vegetables to the meal that is significantly different across BMI categories and this needs to be investigated further. Unfortunately, this study was unable to accomplish this as it did not analyse the entirety of women's meal intake. A separation of types of fruits or vegetables by mealtime would also help in identifying differences between BMI categories as some fruits and vegetables contain more starch and calories than others. Different fruits and vegetables can also be prepared differently which may alter calorific and nutrient intake. For example, Metcalf et al. (1998) found Pacific were more likely to boil or steam vegetables while NZE women were more likely to fry in vegetable oils. Therefore, the preparation during mealtimes needs to be investigated further.

Overall, Pacific women's intake of fruits and vegetables was lower at mealtimes than NZE. Many studies have shown a growing transition from traditional foods including fruits and vegetables to westernised, highly processed and energy-dense foods in Pacific people (Veatupu et al., 2019, Dancause et al, 2012, Hawley and McGarvey, 2015, Sievert et al., 2019). The Ministry of Health (2020a) Adult Nutrition survey revealed that Pacific females were 2.83 times more likely to consume fast food or takeaways during the week compared to non-Pacific women which may contribute to the lower intake at mealtimes. Increased intake of pre-prepared meals or takeaways has been associated with reduced likelihood of consuming daily fruit and vegetable recommendations (Gopinath et al., 2016, Jaworowska et al., 2013, Smith et al., 2009, Miura et al, 2009) which aligns with our results.

Of the mealtime categories, more serves of fruits and vegetables were consumed at dinner for obese and normal BMI women of both ethnicities in this study. Similarly, Fayet and Mortensen (2012) found larger meals providing the most energy were generally eaten at dinner, and less at breakfast. This may explain the increase in fruits or vegetables at dinner along with the presence of serves that were 'part of a mixed meal', highlighting that fruits and vegetables are mainly incorporated into the dinner meal.

Differences in overall eating patterns may provide an explanation for differences between ethnicities in fruit and vegetable intake at other mealtimes. NZE women ate fruits or vegetables more frequently across the day than Pacific women. NZE women consumed the most servings at dinner, then lunch, then breakfast whereas Pacific women consumed the highest number of servings at dinner then afternoon tea and lunch revealing an overall later pattern of consumption. Unfortunately, there is currently no research on the general meal frequency of the NZ population and whether the differences in timing of fruit and vegetable intake are consistent with general main meal timing or as a snack. One Australian study by Fayet and Mortensen (2012) based on the Australian National Nutrition survey, found three distinct energy peaks at breakfast lunch and dinner with two to three smaller energy peaks in-between in keeping with the mealtimes used in this study. One small 1998 study of 30 NZ women showed 97% of women had lunch and dinner while only 50% of participants ate breakfast (Metcalf et al., 1998). They also found afternoon tea to be the most common time to consume a snack. It may be that Pacific women were more likely than NZE to snack on fruits or vegetables at afternoon tea or at supper time. However, an issue of characterizing meals by clock time is the disregard for energy density and nutrient composition (Fayet-Moore et al., 2017). The Ministry of Health (2020a) revealed Pacific were less likely to consume breakfast than non-Pacific women at a ratio of 1:0.80 and were 1.25 times more likely to consume breakfast only zero to two times per week. Utter et al. (2006) found 40.8% of Pacific adolescents skipped breakfast compared to 7.7% of NZE and 9.7% of Pacific adolescents skipped lunch compared to 3.8% of NZE. Therefore, it is possible that Pacific were more likely to consume food later in the day which may explain why their fruit and vegetable intake peaks later in the day than NZE women. Further, the cut-off times used in this study may not be suitable to capture the main meals eaten by Pacific women i.e., the true lunch meal may be consumed during the afternoon tea period. A glimpse at the raw 5d-FR suggests this to be true. Therefore, the increased fruit or vegetable intake in Pacific compared to NZE women at supper and afternoon tea may be related to inclusion in meals rather than snacks as they sleep later in the morning, therefore shifting their general food intake to later in the day and go to bed later.

Nutrient analysis

The independent investigation between BMI and BF% groups in each ethnicity, revealed no differences in energy, fat, sugars or starch intake. This is surprising as multiple reviews have identified the inverse relationship between obesity and energy intake (Baqai and Wilding, 2014, Cruz-Requena et al, 2016, Zierle-Ghosh and Jan, 2020). Johansson et al. (2001) found significant under-reporting of energy-dense foods and over-reporting of fruits and vegetables was common, thus explaining the lack of variance.

This study found carbohydrate intake from fruit and vegetables, total carbohydrates and total sugars were increased in women with a normal BF% compared to those with a high BF%. Interestingly, Jarvi et al. (2016) found an intervention to increase fruit and vegetables resulted in increased monosaccharide intake. The current recommendation of carbohydrates for the prevention of chronic disease is 45-55% of total energy intake (Reynolds et al., 2019). However, Marckmann et al. (2000) found a high carbohydrate (59% of energy), low sucrose diet (2.5% of energy), high in fruits and vegetables, was associated with lower CVD risk. Therefore, the higher carbohydrate intake from fruit and vegetables is a positive finding.

Carbohydrate intake from fruit and vegetables was higher in Pacific women with an obese BMI than NZE. Although Pacific women consumed significantly more serves of starchy vegetables, the lack of difference in starch, along with a higher percentage of sugar from fruit and vegetables compared to NZE, suggests differences in dietary sources of carbohydrate between ethnicities. University of Otago and Ministry of Health (2011) found Pacific consumed more starchy vegetables and bread, however NZE consumed more sugars from milk and milk products which may contribute to total sugar intake. However, when separated by BF%, Pacific women with a high BF% had higher total carbohydrate and sugar intake than NZE suggesting starchy vegetables may be adding to intake rather than replacing. Metcalf et al. (2014) reported Pacific women consumed larger serves of starchy vegetables when compared to NZE.

Similarly, when looking at BMI categories, the percentage of fat consumed from fruits and vegetables was higher in Pacific women compared to NZE, despite fewer servings of vegetables. Metcalf et al. (2014) found Pacific women were significantly more likely than NZE to fry vegetables in animal fat and use coconut cream. This study included deep-fried and fried vegetables such as takeaway french fries and hashbrowns. As mentioned, Pacific are 2.83 times more likely to consume takeaways than non-Pacific which may account for increased fat intake from vegetables (Ministry of Health, 2020a). While there was no difference in total intake, it suggests that increasing fruit or vegetable intake may lead to increased overall fat intake.

Pacific women consumed significantly less total dietary fibre than NZE in both extremes of BMI and BF% groups. Metcalf et al. (1998) and Metcalf et al. (2008) also found Pacific women consumed less fibre than NZE. However, differences between obese and normal BMI and between normal and high BF% was seen in NZE only. Those with a normal BF% or normal BMI had significantly higher total dietary fibre intake and specifically, fibre intake from fruit and vegetables than a high BF% or obese BMI groups. However, all groups, including Pacific, consumed less fibre than the SDT of 25g/day (National Health and Medical Research Council, 2006).The Ministry of Health (2012a) also found NZ women were consuming similar grams of fibre. The low intake of fibre is concerning as recent research has highlighted the value of dietary fibre in management of obesity (Cui et al., 2019, Howarth et al., 2001, Davis, 2018) and obesity-related diseases (Bazzano et al., 2003, Reynolds et al., 2019) and this study found fibre was significantly correlated with BMI and BF%.

The percentage of sodium from fruit and vegetables and total sodium was higher in those with an obese BMI compared to a normal BMI. When comparing servings, the difference in sodium may be contributed to by intake of more processed foods such as takeaways, pre-made soups and tomato-based sauces. Metcalf et al. (2008) reported around 75% of sodium intake is a result of processed foods.

Garcia (2012) found Vitamin A status to be inversely related to adipogenesis. This study found both total Vitamin A and the percentage from fruit and vegetables was higher in NZE women with a normal BMI. No difference was seen in Pacific women, however, their total vitamin A intake and percentage of vitamin A from fruit and vegetables overall was significantly lower than NZE women. This is unsurprising due to the lower intake of vitamin-A-rich vegetables.

Vitamin C intake was lower in those with an obese BMI which aligns with a study by (Halgord et al, 2019) which showed vitamin C supplementation led to a significant reduction in BMI. In alignment, citrus fruit intakes were slightly lower in those with an obese BMI although not statistically significant. NZE women had higher intakes of total folate and the percentage of iron from fruit and vegetables than Pacific women. Folate is important in DNA methylation including genes involved in adipogenesis (McKay et al., 2020). Low iron has been associated with obesity (Lecube et al., 2012, McKay et al., 2020) and shown to play a role in appetite regulation through increasing leptin (Gao et al, 2015). Intake of these nutrients likely reflects the higher intake of green leafy vegetables categorised as green vitamin-A-rich (Singh et al., 2001). A study by Giskes et al. (2002) found Australian adults with higher deprivation, consumed lower intakes of vitamin A, vitamin C, and folate from fruits and vegetables. University of Otago and Ministry of Health (2011) found the same trend for folate intake.

According to Ministry of Health (2012b) Pacific are twice as likely than non-Pacific to experience food insecurity. This study found Pacific had higher rates of deprivation than NZE, which may explain some difference between intakes.

Conclusion

This study found intake of fruit and vegetable servings was well below the newly recommended daily five vegetables and two fruit for the majority of women regardless of body composition or ethnicity despite a significant correlation between mean combined daily serves and BMI, BF% and WC. In particular, cruciferous, green and yellow vitamin-A-rich and other non-starchy vegetables were inversely correlated with BMI. Overall, only total vegetable serves were a significant predictor of BMI and BF% for the whole group and only in NZE when separated by ethnicity. The low consumption of fruits and vegetables was reflected in overall nutrient intake. Pacific women consumed more fat and sodium from fruits and vegetables suggesting differences in food preparation.

Pacific women mostly consumed fruits and vegetables later in the day than NZE, although the largest intake of fruits or vegetables was consumed at dinner for both ethnicities. The most commonly consumed fruits and vegetables were carrots, onions, lettuce, tomatoes and potato.

Future promotion of fruit and vegetable intake, particularly cruciferous and vitamin-A-rich, will be valuable for all women in order to achieve recommended nutrient intakes and to reduce the risk of obesity and obesity-related diseases. Promotion should include a focus on distribution, such as earlier in the day for Pacific women and between meals for NZE women, and should emphasise replacement of energy-dense foods with pure servings of fruits or vegetables along with healthy cooking methods such as using little oil/animal fat or added salt.

Chapter 4: Recommendations

Background: Obesity is a significant health issue in NZ; affecting one in three adults (Ministry of Health, 2020a). Fruit and vegetable intake may influence body composition but the intake of Pacific and NZE women with and without obesity is currently not fully understood. The aim of this study was to conduct an in-depth investigation of the fruit and vegetable intake (quantity, quality and habits) of NZE and Pacific women participating in the PROMISE study, to determine links with body composition outcomes. The results of this study aid in understanding current patterns of fruit and vegetable intake and associations with body composition outcomes. These results will help guide recommendations related to fruit and vegetable utilisation in the prevention or management of obesity with consideration for ethnic differences.

Main findings and recommendations

Objectives:

Objective 1: To analyse and compare types of fruit and vegetables and their nutritional contribution to dietary intake – quantity and quality (single items versus combined dishes) – of Pacific and NZE women with different body composition profiles.

Findings: Only 15.5% of NZE and 26.1% of Pacific consumed the recommended five serves vegetables daily and 51.6% of NZE and 26.8% of Pacific women met the fruit recommendations of two serves daily. Pacific women consumed significantly fewer combined daily serves than NZE, regardless of their body composition (BMI or BF%). Regardless of body composition or ethnicity, women consumed well below the recommended dietary intake of fruits and vegetables, with Pacific women consuming less than four daily serves and NZE less than five. Overall, there was low diversity within fruit and vegetable categories.

Combined daily serves and vegetables serves were significantly inversely correlated with BMI, BF% and WC. For every one serve increase in total vegetable serves, women's BMI reduced by 0.65kg/m^2 and BF% by 1.16%. However, a statistically significant difference in vegetable serves between obese and normal BMI groups was found in NZE only. Cruciferous, green and yellow vitamin-A-rich vegetables and other non-starchy vegetables were inversely correlated with BMI when adjusted for ethnicity, however differences in actual intake between obese and normal BMI groups were only found for cruciferous and yellow vitamin-A-rich vegetables in NZE women only.

No differences in total energy intakes were seen between BMI groups suggesting misreporting may be present in this study. Differences between energy from fruit and vegetables only was not apparent between extreme BMI groups in either ethnicity or between ethnicities. Pacific women consumed more fat from fruit and vegetables than NZE despite consuming fewer servings. They also consumed more total carbohydrates and sugars when investigated by BF% groups. Pacific women consumed significantly less dietary fibre than NZE although both ethnicities consumed below the SDT of 25g/day. NZE consumed more cruciferous and vitamin-A-rich vegetables than Pacific women, and this is reflected in their higher total vitamin A, total folate, and percentage of iron from fruits and vegetables intakes. Total sodium was higher in those with an obese BMI than normal BMI. Total vitamin C and vitamin C intake from fruit and vegetables only was lower in obese BMI than normal BMI for both Pacific and NZE.

It is therefore recommended for women to increase their total vegetable serves consumed per day, specifically vitamin A rich and cruciferous vegetables, such as spinach, pumpkin, cabbages, courgettes and capsicum. It is recommended to promote low-fat, no added salt preparation methods such as steaming rather than deep-frying.

Objective 2: To analyse and compare the distribution throughout the day of fruit and vegetable intakes (eating habits) of Pacific and NZE women with different body composition profiles.

Findings: NZE women with a normal BMI consumed more total serves (including serves used within a dish) and pure serves of fruit and vegetables at lunch and dinner than NZE with an obese BMI. No differences were seen in Pacific women across different BMI groups. Overall, NZE consumed more serves at each meal time than Pacific women. Pacific women had a later pattern of consumption of fruits and vegetables; tending to consume most at lunch, afternoon tea and dinner, while NZE consumed most at breakfast, lunch and dinner. This may be related to differences in overall dietary and lifestyle patterns such as Pacific being more likely to skip breakfast and consume meals later in the day due to having later wake and sleep times (Ministry of Health, 2020a). However, the largest intake of fruits or vegetables was consumed at dinner for both ethnicities. While there does not seem to be a significant difference in fruit and vegetable intake at specific mealtimes across BMI categories, there may be cultural differences between ethnic groups that will impact the way interventions are received and carried out. For example, if breakfast is not commonly eaten, as seen in Pacific women (Ministry of Health, 2020a), recommending to increase fruit or vegetable intake may result in more being eaten at one time or one meal, therefore resulting in a higher energy load, depending on food preparation methods. Promotion of increasing the quantity of fruit and vegetables with meals and between meals as pure snacks may be beneficial to meet the requirements, to lower overall energy intake and to reduce the risk of obesity. However, guidelines should focus on advising that fruit and vegetables should be incorporated in replacement of energy-dense foods, particularly in those with a higher BMI. For Pacific women, encouragement of fruit and vegetable intake earlier in the day may further aid in improving intakes while for NZE to incorporate more as snacks between meals.

Objective 3: To analyse and compare the diversity and preferences of fruit and vegetable intakes of Pacific and NZE women with different body composition profiles.

Findings: NZE women consumed more servings of green and yellow vitamin-A-rich vegetables, other non-starchy vegetables, as well as vegetables containing starch and tomatoes, than Pacific women, who in turn consumed more servings of starchy vegetables regardless of BMI. Based on the mean intake across five days of food records, no full serving of one fruit or vegetable type was consumed by either ethnicity or BMI group on one day. In other words, over five days, women did not consistently consume enough cruciferous vegetables or vitamin-C-rich fruit to equate to a full serve each day i.e. they may only have had a full serve on one of the five days or partial serves on most days. The most consumed fruit were banana and apples followed by citrus fruits, although serving sizes were small. The vitamin-A-fruit category (e.g. apricots, mangos, melons) was least consumed. Cruciferous vegetables, particularly broccoli and cabbage, and yellow vitamin-A-rich vegetables, such as carrots and capsicums, were the food groups most often consumed from. Most consumed vegetables were onions, carrots, tomatoes, lettuce and potatoes by both ethnicities.

These findings show that both NZE and Pacific women, regardless of BMI or BF%, would benefit from increasing their total daily fruit and vegetable intake, and particularly cruciferous vegetables, green and yellow vitamin-A-rich fruit and vegetables, non-starchy vegetables, and vegetables containing starch. It also shows need to increase diversity and range between and within fruit and vegetable categories. Though women may be consuming these foods, the frequency and serving size fall short of the current recommendation, therefore contributing to low fibre and micronutrient intakes. Increasing starchy vegetables should be in consideration of other dietary carbohydrate intakes as our results show Pacific women had higher total carbohydrate intake but no difference in percentage of carbohydrates from fruit and vegetables. However, on average of five days, both ethnicities consumed less than one serving per day and they also did not reach the recommended total carbohydrate intake. Therefore, increasing starchy vegetables should also be considered as part of increasing fruit and vegetable intake. Due to the high levels of sodium and fat associated with fruit and vegetable intake in Pacific women, consideration of food preparation and cooking methods including takeaway foods should be factored in for in future recommendations. Examples include homemade potato fries and using small amounts of oil to fry.

The use of BF% improved the accuracy of identifying obesity as BMI can sometimes misclassify participants who have higher muscle mass (Oliveros et al., 2014). However, using the different body composition measures of BMI and BF% did not reveal any differences in findings but rather aided in accurately identifying the influence of fruit and vegetable intake of body composition. Either BMI or BF% could therefore be use to investigate body composition outcomes in relation to fruit and vegetable intakes.

Strengths

Strengths of this study include the large and relatively even sample size of 161 NZE and 142 Pacific women. The collection of data was a strength as the study used the gold-standard 5d-FR including two weekend and three weekdays to gather a true overview of usual diet. Participants were trained in estimating and documenting food along with visual aids to assist in completing the food records. One-on-one interviews were conducted by NZ Registered Dietitians to clarify portion sizes, timing of food intake, and identifying missed foods, thus heightening the accuracy of the data.

Another strength was to analyse not only the overall quantity but also specific types of fruit and vegetable intakes, the timing of intake and the nutrient contribution to overall diet in relation to body composition and in context of ethnicity. Further, this study was able to compare different BF% groups due to the gold-standard DXA measurements in addition to

BMI categories (Oliver et al., 2011). This study provides information concerning fruit and vegetable intake within two NZ ethnicities that is valuable in creating future health promotion campaigns. This is timely with the recently updated serving size guidelines that recommends increased fruit and vegetable intake (Ministry of Health, 2020b).

Limitations

The first limitation of this study is the cross-sectional design that only captures a snapshot of time and does not allow for a control group or for assessing usual intakes. Participants in this study were intentionally recruited to create a 50/50 divide of obese and normal BMI groups. Therefore, the demographic composition does not completely mirror that of the NZ population. Further, the use of self-reported weight and height as a screening tool resulted in the presence of "overweight" groups. Limitations also include the use of non-parametric data due to data not being normally distributed although this is common in many studies analysing diet including those referenced in this study (McKay et al., 2020, Metcalf et al., 2014, Giskes et al., 2002). Unfortunately, the sample size of some BMI groups within an ethnicity, e.g. overweight BMI, was too small to assume the theorem of central tendency (Kwak and Kim, 2017) resulting in the use of non-parametric testing.

Another limitation of this study were the assumptions made by the author regarding fruit and vegetable intake as part of a meal (Appendix A: Supplementary methods table 1). Some fruits or vegetables were part of a mixed meal, yet the quantity or type was unidentified by participants e.g. "subway sandwich". Therefore, assumptions were made based on common food composition of commercial foods as consumed quantities, however these may not be accurate for all participants. This study was further limited as it did not evaluate the percentage of the fruit or vegetable to the overall meal or distinguish between snacking or meal episode due to categorising meal times by clock time instead of energy density or eating episode. It also did not analyse the entirety of energy intake at each meal time.

Participant recruitment was aimed at achieving an even participant number of obese and normal BMI Pacific and NZE women, and not at representing the demographic proportions seen in NZ society. Therefore, although recruitment was conducted across all seasons, participant numbers varied across seasons. However, participants consumed 2-3 servings across seasons with minimal differences between seasons.

Further limitations include not including and adjusting for sleep/wake cycles and physical activity levels.

Recommendations:

If this study were to be repeated, the following recommendations should be considered:

- The isolation of all fruits and vegetables from meals, regardless of portion, to find the true quantity and diversity of intake. In addition, to analyse all fruits and vegetables as a percentage of the meal they are consumed in by analysing total food and nutrient composition of each meal, to understand extra energy and macro nutrient intake associated with fruit and vegetable intake.
- To identify in one-on-one interviews with NZ Registered Dietitians, all fruit and vegetable proportions of a meal, particularly commercial foods e.g. "subway sandwich" that were missed in our interviews.

For future research, the following recommendations should be considered:

- To analyse the contribution of fruits and vegetables to overall meals, specifically quantity and types incorporated at mealtimes.

- To evaluate total eating frequencies and complete food patterns, not just of fruit and vegetables, of Pacific and NZE women to understand how fruits and vegetables are incorporated into a daily diet
- To understand total eating frequencies, patterns and energy intake, not just fruit and vegetables, of women with an obese and normal BMI to understand how fruit and vegetable incorporation differs
- To analyse cooking methods and ingredients involved in the preparation of fruits and vegetables consumed between obese and normal BMI Pacific and NZE women such as analysing recipes and utilizing one-on-one interviews for the purpose of obtaining preparation information.
- To analyse mealtimes using sleep-wake patterns provided by participants to understand when in the day fruit and vegetables are consumed as meals. For example, breakfast may be later or earlier by clock-time depending on work hours or wake-up time.
- To analyse fruit and vegetables consumption in conjunction with metabolic markers and the gut microbiome to understand the influence on obesity

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Appendix A: Supplementary Methods

Supplementary Methods Table 1: Fruit and vegetable percentages of mixed meals

Food	Conversion Factor	Reference analysis
Apple Sauce	0.9	Countdown
Cranberry Sauce	0.35	Countdown
Pineapple Pie	0.37	Foodworks recipe
Pumpkin Soup	0.4	Countdown: Range: 35-60% Vegetable
Otai	0.51	Foodworks Recipe
Tomato-based Pasta Sauces	0.95	Countdown: Range: 90-99%
Dumplings	0.25	Countdown Range: 21-30%
Potato Salad	0.75	Countdown
Tomato Paste	0.99	Countdown
Tomato Soup	0.90	Countdown
Chicken and Vegetable Soups	0.4	Countdown Range: 35-45%
Samosa	0.50	Countdown
Individual Apple Pie	0.30	Countdown
Apple Crumble	0.35	Countdown Range: 35-40% (majority 35%)
Mashed Potato and Gravy	0.50	Estimated based on weight and cup size
Salsa (Tomato + Capsicum)	0.7	Countdown Range: 68-72%
Spinach Quiche	0.10	Countdown Range: 7-10%
Enchilada Sauce	0.27	Countdown
Mushroom Soup	0.10	Countdown Range: 9-15%
Vegetable Soup	0.50	Countdown Range: 41-55%
Chicken and vegetable meal	0.18	Countdown
Onion Rings	0.53	Countdown
Pea and Ham Soup	0.35	countdown Range: 15-81% (Majority around 35%)
Smoothies (unknown recipe)	0.50	Based on other participants FW entries
Tempura battered vegetables	0.60	Countdown
Pineapple Fritter	0.50	Estimated based on Foodworks weight
Maketu pie	0.30	Maketu brand
Subway (unknown recipe)	6" = 1 serving	Estimated
Coleslaw (unknown recipe)	0.75	Countdown Range: 67-78%
French Fries	0.95	Countdown

Retrieved from: www.countdown.co.nz

Supplementary Methods Table 2: Fruit and Vegetable Groups

	Fruit	
VCF	Vitamin C	Mandarins, Oranges, Kiwifruit, Grapefruit, Lime, Lemon
VAF	Vitamin A	Apricot, Mango, Peaches, Persimmon, Plum, Tamarillo, watermelon, melon, gooseberry
B	Berries	Blueberry, strawberry, raspberry, Cranberry,
OF	Other fruits	Apple, banana, all other fruit (fresh, tinned, dried), grape, , guava, papaya, lychee, passionfruit, prune, raisin, grapes, pineapple, feijoa, pears
	Vegetables	
AV	Allium vegetables	Onion, Leeks, Shallots, spring onion
CV	Cruciferous vegetables	Broccoli, Cauliflower, Kale, Brussel Sprouts, Cabbage, red cabbage, Bok Choy, Cucumber, Turnip, Coleslaw, radish
GVAV	Green Vitamin A rich vegetables	Green: Puha, Watercress, Taro leaves, Silverbeet, Spinach, Lettuce, Courgette
YVAV	Yellow Vitamin A Rich Vegetables	Yellow/Orange: Carrot, Capsicum, red capsicum, Kumara, Pumpkin
NSV	Other non-starchy vegetables	Mushroom, celery, mung beans, eggplant, rhubarb, asparagus, artichoke, coconut, chilli
SV	Starchy vegetables (15g/serve)	Potato, Yam, Parsnip, Swedes, Taro, Green Banana, Sweetcorn, Breadfruit, Cassava
VCS	Vegetables contributing starch (~7g/SERVE)	Peas, green beans, squash, traditional frozen vegetable mix, beetroot,
T	Tomatoes	Fresh, Canned, Cooked
MM	Mixed meals	

Supplementary Methods Table 3: Meal Times

Number	Meal	Timing
1	Early Snack	0000 - 0559
2	Breakfast	0600 – 1000
3	Morning Tea	1001 – 1159
4	Lunch	1200 – 1400
5	Afternoon Tea	1401 – 1659
6	Dinner	1700 – 2030
7	Supper	2031 - 1159

Appendix B: Supplementary Results

Nutrients

Supplementary Results Table 1: Vitamin intakes separated by ethnicity and BMI category

Vitamin		BMI; Pacific N=142				BMI; NZE N=161				
		Obese N=75(24.8%) Median (25-75)	**Overweight N=31(0.1%)** Median (25-75)	**Normal BMI N=36(11.9%)** Median (25-75)	**p-value^**	**obese N=71(23.4%)** Median (25-75)	**Overweight N=12(3.9%)** Median (25-75)	**Normal BMI N=78(25.7%)** Median (25-75)	**p-value^**	**p-value***
Thiamine (mg)	*Fruit and Vegetables only*	0.18 (0.12, 0.27)	0.26 (0.13, 0.36)	0.22 (0.14, 0.28)	0.10	0.20 (0.15, 0.31)	0.19 (0.16, 0.27)	0.20 (0.15, 0.31)	0.97	0.28
	Total Food	1.27 (0.89, 1.68)	1.19 (1.11, 1.48)	1.15 (0.89, 1.46)	0.79	1.18 (0.95, 1.41)	1.15 (0.98, 1.28)	1.18 (0.94, 1.60)	0.76	0.93
	%	15.2 (7.33, 22.3)	18.0 (12.7, 29.5)	17.5 (13.8, 23.9)	0.08	17.0 (13.8, 23.9)	16.2 (10.2, 23.8)	17.1 (11.3, 23.0)	0.93	0.30
Niacin (mg)	*Fruit and Vegetables only*	4.46 (2.83, 6.32)	4.98 (2.95, 7.77)	4.50 (3.15, 6.59)	0.41	4.15 (3.09, 6.53)	4.40 (2.99, 5.59)	5.09 (3.48, 6.84)	0.46	0.54
	Total Food	36.7 (27.5, 45.4)	34.1 (29.5, 44.5)	34.7 (28.3, 43.8)	0.77	34.5 (29.7, 38.5)	34.9 (32.8, 37.9)	33.7 (29.6, 39.5)	0.83	0.75
	%	11.6 (8.47, 17.2)	15.7 (9.15, 22.2)	13.0 (9.24, 19.8)	0.71	13.0 (7.89, 19.2)	13.6 (9.11, 16.1)	14.4 (11.0, 20.3)	0.58	0.25
Riboflavin (mg)	*Fruit and Vegetables only*	0.18 (0.12, 0.27)[g]	0.20 (0.14, 0.37)	0.19 (0.12, 0.26)[h]	0.68	0.24 (0.15, 0.34)[dg]	0.34 (0.19, 0.49)	0.30 (0.22, 0.44)[dh]	**0.02**	**<0.01**
	Total Food	1.61 (1.18, 2.19)	1.93 (1.26, 2.24)	1.64 (1.10, 1.99)	0.40	1.78 (1.48, 2.13)	1.99 (1.70, 2.55)	1.77 (1.42, 2.15)	0.31	0.07
	%	11.1 (7.02, 19.3)	12.3 (7.97, 21.8)	12.3 (8.21, 16.2)[h]	0.83	12.6 (8.28, 19.8)[d]	15.1 (10.0, 21.4)	17.6 (11.1,25.2)[dh]	**0.02**	**<0.01**
B6 (mg)	*Fruit and Vegetables only*	0.49 (0.27, 0.67)	0.51 (0.29, 0.83)	0.50 (0.30, 0.71)[h]	0.72	0.54 (0.33, 0.77)[d]	0.52 (0.26, 0.93)	0.67 (0.47, 0.94)[dh]	**0.03**	**<0.04**
	Total Food	2.22 (1.56, 2.86)	2.46 (1.90, 3.22)	1.82 (1.50, 2.74)	0.24	2.07 (1.50, 2.42)	2.11 (1.33, 2.73)	2.30 (1.88, 2.74)	0.07	0.16
	%	23.3 (12.0, 32.8)[g]	23.3 (12.1, 35.2)	25.0 (16.8, 30.7)[h]	0.78	28.7 (18.7, 38.5)[g]	29.5 (18.1, 29.2)	31.3 (22.2, 29.2)[h]	0.49	**<0.01**
Folate (µg)	*Fruit and Vegetables only*	66.3 (36.0, 93.7)[g]	73.9 (45.4, 101)	67.7 (41.4, 101)[h]	0.40	78.7 (46.1, 122)[g]	88.9 (54.6, 144)	96.0 (59.5, 138)[h]	0.27	**<0.01**

Vitamin		BMI; Pacific N=142 Obese N=75(24.8%) Median (25-75)	Overweight N=31(0.1%) Median (25-75)	Normal BMI N=36(11.9%) Median (25-75)	p-value^	BMI; NZE N=161 obese N=71(23.4%) Median (25-75)	Overweight N=12(3.9%) Median (25-75)	Normal BMI N=78(25.7%) Median (25-75)	p-value^	p-value*
	Total Food	244 (167, 336)[g]	304 (219, 389)	250 (180, 337)[h]	0.16	308 (256, 401)[dg]	308 (288, 420)	370 (294, 445)[dh]	0.04	**<0.01**
	%	26.6 (16.6, 35.3)	27.4 (13.7, 40.2)	26.0 (19.1, 38.6)	0.56	25.4 (19.3, 36.2)	26.1 (22.0, 34.3)	26.7 (18.1, 37.7)	0.96	**0.02**
B12 (µg)	*Fruit and Vegetables only*	0.04 (0.00, 0.17)	0.07 (0.02, 0.24)	0.02 (0.00, 0.25)	0.15	0.09 (0.00, 0.29)	0.05 (0.00, 0.28)	0.13 (0.02, 0.29)	0.69	0.07
	Total Food	3.95 (2.83, 5.30)	3.82 (2.76, 5.47)	3.80 (2.97, 4.58)	0.71	3.63 (2.81, 4.56)[d]	4.02 (3.43, 4.84)[de]	3.14 (2.31,4.27)[de]	**0.02**	**0.02**
	%	0.72 (0.00, 3.96)[g]	2.24 (0.32, 7.20)	0.52 (0.06, 6.96)	0.17	2.63 (0.00, 6.85)[g]	1.17 (0.00, 7.68)	4.01 (0.33, 9.31)	0.27	0.95
Vitamin C (mg)	*Fruit and Vegetables only*	39.4 (15.6, 62.0)[a]	34.1 (17.2,70.6)	55.4 (31.9, 78.7)[a]	0.08	43.1 (25.1, 78.7)[d]	47.4 (33.4, 101)	64.1 (36.7, 92.7)[d]	0.05	**<0.01**
	Total Food	50.0 (31.1, 80.6)[a]	45.9 (29.9, 102)	69.3 (47.9, 104)[a]	0.06	53.1 (33.6, 105)[d]	57.2 (47.6, 107)	79.1 (55.0, 106)[d]	0.06	**<0.01**
	%	78.2 (52.8, 90.2)	76.0 (57.5, 87.3)	80.1 (59.8, 93.9)	0.66	82.2 (70.3, 90.8)	73.8 (64.6, 94.0)	87.6 (76.9, 93.6)	0.20	**0.02**
Vitamin A (µg)	*Fruit and Vegetables only*	151 (51.4, 359)[g]	172 (84.5, 337)	188 (103, 329)[h]	0.75	314 (176, 510)[g]	316 (221, 759)	426 (265, 628)[h]	0.11	**<0.01**
	Total Food	529 (323, 726)[g]	608 (404, 858)	546 (344, 829)[h]	0.53	830 (581, 1011)[dg]	900 (657, 1140)	821 (641, 1069)[dh]	0.67	**<0.01**
	%	30.7 (13.6, 52.6)[g]	32.5 (19.4, 47.0)	35.1 (21.2, 46.8)[h]	0.91	43.8 (26.9, 58.3)[dg]	38.2 (30.3, 57.5)	53.2 (38.9, 67.0)[dh]	0.03	**<0.01**
Vitamin E (mg)	*Fruit and Vegetables only*	1.42 (1.00, 2.16)[g]	2.02 (0.92, 2.69)	1.80 (1.09, 2.39)[h]	0.41	1.86 (1.13, 2.87)[dg]	1.67 (1.27, 3.49)	2.28 (1.48, 3.16)[dh]	0.10	**<0.01**
	Total Food	7.95 (5.93, 9.35)[g]	9.95 (6.74, 11.4)	9.72 (6.31, 11.5)	0.07	8.94 (7.07, 11.4)[dg]	9.52 (8.83, 12.5)	10.1 (8.25, 12.6)[d]	0.06	**<0.01**
	%	18.7 (13.6, 28.0)	20.0 (14.3, 26.6)	20.2 (14.8, 28.3)	0.89	20.8 (14.5, 30.2)	17.0 (13.6, 23.5)	22.1 (14.8, 30.3)	0.50	0.56

Percentage: calculated by dividing fruit and vegetable only by total for each participant and average for new variable.
Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance
a-h: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05.
Obesity: BMI ≥30; *Overweight:* BMI≥25<30; *Normal BMI:* BMI ≥18.5-≤24.9

Supplementary Results Table 2: Mineral intakes separated by ethnicity and BMI category

		BMI; Pacific N=142				**BMI; NZE N=161**				
Mineral		**Obese N=75(24.8%)** Median (25-75)	**Overweight N=31(0.1%)** Median (25-75)	**NORMAL BMI N=36(11.9%)** Median (25-75)	**p-value^**	**Obese N=71(23.4%)** Median (25-75)	**Overweight N=12(3.9%)** Median (25-75)	**Normal BMI N=78(25.7%)** Median (25-75)	**p-value^**	**p-value***
Sodium (mg)	*Fruit and Vegetables only*	240 (114, 402)^{ab}	428 (194, 744)^{b}	372 (209, 504)^{a}	0.07	279 (126, 404)	261 (119, 402)	183 (164, 529)	0.47	**0.03**
	Total Food	2660 (1959, 3415)^{a}	3309 (2702, 4254)^{ab}	2801 (2039, 3494)^{bh}	**<0.01**	2660 (2332, 3337)^{d}	2427 (2125, 2998)	2320 (1865, 2729)^{dh}	0.47	**<0.01**
	%	8.71 (4.78, 14.3)^{ab}	13.1 (5.78, 24.4)^{a}	12.8 (7.07, 19.6)^{b}	**0.03**	10.4 (4.91, 16.3)^{d}	9.70 (6.11, 15.3)	13.2 (7.15, 22.2)^{d}	0.07	**0.02**
Calcium (mg)	*Fruit and Vegetables only*	52.0 (31.2, 78.8)^{g}	65.6 (42.4, 81.0)	59.3 (34.2, 88.9)^{h}	0.09	67.7 (46.4, 127)^{dg}	87.3 (48.2, 142.2)	101 (62.6, 139)^{dg}	0.09	**<0.01**
	Total Food	593 (410, 836)^{g}	683 (548, 861)	614 (468, 837)	0.39	839 (640, 1070)^{g}	1005 (853, 1146)^{e}	795 (680, 988)^{e}	0.09	**<0.01**
	%	9.11 (5.44, 15.8)	8.62 (5.29, 12.0)	8.08 (5.64, 15.0)	0.90	9.05 (5.46, 16.1)	7.74 (5.28, 14.0)	12.0 (7.84, 17.0)	0.09	0.20
Magnesium (mg)	*Fruit and Vegetables only*	60.3 (40.9, 84.6)	71.2 (44.1, 108)	61.5 (39.2, 87.7)	0.46	60.1 (43.9, 82.0)	50.6 (40.5, 100)	70.0 (50.5, 95.6)	0.13	0.17
	Total Food	254 (197, 322)^{g}	279 (241, 367)	266 (235, 309)	0.11	302 (251, 380)^{dg}	314 (279, 418)	327 (281, 418)^{cd}	0.13	**<0.01**
	%	23.4 (17.4, 31.9)	25.9 (15.8, 33.5)	22.9 (16.8, 29.7)	0.90	20.7 (14.9, 25.7)	18.3 (15.3, 20.7)	20.3 (16.1, 27.8)	0.46	0.07
Potassium (mg)	*Fruit and Vegetables only*	887 (690, 1262)	1114 (664, 1555)	946 (634, 1206)	0.24	953 (674, 1271)	979 (663, 1483)	1086 (804, 1416)	0.12	0.71
	Total Food	2561 (1982, 3009)^{ag}	2963 (2274, 3733)^{ab}	2588 (2080, 3109)^{ab}	**0.046**	2882 (2504, 3413)^{g}	3144 (2558, 3688)	3103 (2636, 3653)^{h}	0.12	**<0.01**
	%	37.3 (28.4, 46.5)	36.8 (29.3, 42.8)	35.4 (31.3, 44.0)	0.98	33.9 (24.2, 41.0)	32.1 (27.4, 40.7)	34.8 (28.5, 45.2)	0.24	0.28
Phosphate (mg)	*Fruit and Vegetables only*	159 (108, 223)	194 (131, 289)	162 (111, 232)	0.33	164 (113, 234)	135 (120, 211)	178 (127, 251)	0.59	0.44
	Total Food	1250 (910, 1491)^{ag}	1234 (1098, 1561)	1171 (966, 1420)^{ah}	0.38	1381 (1213, 1594)^{g}	1474 (1391, 1561)	1417 (1217, 1587)^{h}	0.59	**<0.01**
	%	14.4 (9.73, 18.4)	14.5 (8.94, 24.8)	14.7 (10.3, 19.7)	0.61	12.2 (8.43, 17.6)	10.2 (8.33, 13.6)	12.7 (9.58, 18.9)	0.33	0.49
Iron (mg)	*Fruit and Vegetables only*	1.44 (0.95, 2.05)^{ag}	1.98 (1.69, 2.59)^{a}	1.59 (1.16, 2.67)^{h}	0.96	1.89 (1.33, 3.20)^{dg}	2.03 (1.60, 4.02)	2.33 (1.69, 3.27)^{dh}	0.26	**<0.01**
	Total Food	11.3 (8.16, 13.6)	11.5 (9.80, 15.0)	11.7 (9.05, 13.4)	0.67	10.5 (8.78, 13.5)	13.5 (10.9, 14.8)	11.5 (9.87, 14.8)	0.26	0.19
	%	14.2 (8.93, 20.4)^{g}	16.8 (13.0, 22.2)	14.8 (11.4, 20.5)^{h}	0.21	19.5 (13.1, 26.7)^{g}	18.2 (15.2, 24.7)	18.8 (12.7, 28.6)^{h}	0.96	**<0.01**
Iodine (µg)	*Fruit and Vegetables only*	5.10 (2.71, 8.51)	5.78 (3.07, 16.9)	5.41 (2.93, 11.3)	0.64	5.14 (2.29, 12.9)	5.90 (3.81, 12.0)	6.92 (3.38, 14.2)	0.51	0.42
	Total Food	77.0 (58.6, 110)^{ag}	101 (71.2, 144)^{a}	91.6 (47.4, 129)	**0.04**	90.8 (74.0, 111)^{g}	109 (101, 133)	93.0 (74.7, 128)	0.51	**0.01**

Mineral		BMI; Pacific N=142 Obese N=75(24.8%) Median (25-75)	Overweight N=31(0.1%) Median (25-75)	NORMAL BMI N=36(11.9%) Median (25-75)	p-value^	BMI; NZE N=161 Obese N=71(23.4%) Median (25-75)	Overweight N=12(3.9%) Median (25-75)	Normal BMI N=78(25.7%) Median (25-75)	p-value^	p-value*
	%	6.56 (3.57, 12.1)	6.40 (3.34, 17.2)	7.73 (3.36, 16.6)	0.90	6.48 (2.94, 12.8)	5.83 (3.27, 11.2)	7.90 (3.57, 14.7)	0.64	0.95
Zinc (mg)	*Fruit and Vegetables only*	1.03 (0.57, 1.71)	1.51 (0.74, 1.64)	0.97 (0.65, 1.83)	0.30	1.12 (0.70, 1.99)	1.12 (0.73, 1.64)	1.39 (0.94, 2.02)	0.30	0.11 0.11
	Total Food	9.85 (7.66, 13.7)	10.21 (7.65, 12.21)	9.62 (8.68, 12.38)	0.99	10.65 (8.32, 12.07)	9.81 (9.61, 11.09)	9.89 (9.61, 11.09)	0.30	0.96
	%	11.0 (5.67, 15.8)	13.1 (7.19, 24.3)	9.81 (7.19, 17.4)	0.33	12.3 (7.53, 18.7)	11.3 (7.09, 18.5)	14.1 (8.60, 22.8)	0.30	0.12
Selenium (µg)	*Fruit and Vegetables only*	1.67 (0.87, 3.95)[ag]	4.47 (1.59, 6.42)[a]	1.59 (0.57, 5.81)[h]	0.38	4.50 (1.77, 9.18)[g]	4.81 (2.99, 14.6)	5.80 (2.80, 10.8)[h]	0.36	**<0.01**
	Total Food	53.6 (39.2, 83.0)	64.5 (48.3, 84.5)	64.1 (39.2, 80.7)	0.48	58.6 (43.7, 72.1)	64.7 (54.7, 85.8)	55.8 (46.6, 73.9)	0.36	0.55
	%	3.23 (1.36, 7.44)[g]	5.88 (3.21, 10.9)	3.63 (1.47, 8.55)[h]	0.12	8.83 (3.01, 14.1)[g]	7.96 (4.80, 12.8)	10.1 (5.14, 18.6)[h]	0.38	**<0.01**

Percentage: calculated by dividing fruit and vegetable only by total for each participant and average for new variable.
Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance
a-h: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05.
Obesity: BMI ≥30
Overweight: BMI≥25<30
Normal BMI: BMI ≥18.5-≤24.9

Fruit and vegetable categories

Supplementary Results Table 3: Intake of servings from fruit and vegetable categories

Fruit/vegetable category	BMI; Pacific = 142 Obese n=75(24.8%) median (25-75)	Overweight n=31(10%) median (25-75)	Normal n=36(11.9%) median (25-75)	p-value^	BMI; NZE =161 Obese n=71(23.4%) median (25-75)	Overweight n=12(3.9%) median (25-75)	Normal n=78(25.7%) median (25-75)	p-value^	p-value*
Citrus fruit	0.05 (0.00, 0.65)	0.22 (0.00, 0.90)	0.28 (0.00, 0.98)	0.37	0.03 (0.00, 0.53)	0.34 (0.01, 0.43)	0.10 (0.00, 0.67)	0.63	0.67
Vitamin-A-rich fruit	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.02)	0.72	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.38	0.76
Berries	0.00 (0.00, 0.00)[g]	0.00 (0.00, 0.00)a	0.00 (0.00, 0.02)[a]	**0.02**	0.00 (0.00, 0.10)[g]	0.04 (0.00, 0.23)	0.00 (0.00, 0.18)	0.24	**<0.01**
Other fruit	0.71 (0.18, 1.27)	0.45 (0.00, 1.27)	0.53 (0.04, 1.05)	0.52	0.69 (0.29, 1.20)	0.49 (0.18, 0.82)	0.94 (0.38, 1.72)	0.10	0.09
Allium vegetables	0.00 (0.00, 0.06)	0.00 (0.00, 0.04)	0.00 (0.00, 0.08)	0.38	0.00 (0.00, 0.05)	0.04 (0.00, 0.12)	0.01 (0.00, 0.10)	0.59	0.36
Cruciferous vegetables	0.14 (0.00, 0.50)	0.14 (0.00, 0.45)	0.00 (0.00, 0.26)[h]	0.67	0.15 (0.00, 0.54)[d]	0.58 (0.05, 1.29)	0.46 (0.14, 0.98)[dh]	**0.01**	**<0.01**
Green vitamin-A-rich vegetables	0.10 (0.00, 0.65)[g]	0.11 (0.00, 0.52)	0.13 (0.00, 0.48)[h]	0.91	0.50 (0.15, 1.15)[g]	0.43 (0.19, 2.04)	0.62 (0.22, 1.38)[h]	0.44	**<0.01**
Yellow vitamin-A-rich vegetables	0.00 (0.00, 0.31)[g]	0.06 (0.00, 0.23)	0.15 (0.00, 0.40)[h]	0.67	0.29 (0.07, 0.55)[dg]	0.08 (0.00, 0.72)	0.47 (0.13, 0.85)[dh]	**0.02**	**<0.01**
Other non-starchy vegetables	0.00 (0.00, 0.00)[g]	0.00 (0.00, 0.18)	0.00 (0.00, 0.08)[h]	0.09	0.06 (0.00, 0.23)[g]	0.14 (0.00, 0.34)	0.16 (0.00, 0.37)[hi]	0.11	**<0.01**
Starchy vegetables	0.71 (0.29, 1.20)[g]	0.89 (0.53, 1.55)	0.66 (0.39, 1.19)[h]	0.20	0.29 (0.15, 0.61)[g]	0.07 (0.00, 0.58)	0.21 (0.04, 0.52)[h]	0.10	**<0.01**
Vegetables containing some starch	0.00 (0.00, 0.00)[g]	0.00 (0.00, 0.23)	0.00 (0.00, 0.13)[h]	0.08	0.08 (0.00, 0.34)[g]	0.06 (0.00, 0.22)	0.11 (0.00, 0.35)[h]	0.64	**<0.01**
Tomatoes	0.00 (0.00, 0.21)[g]	0.06 (0.00, 0.15)	0.00 (0.00, 0.19)[h]	0.72	0.18 (0.00, 0.46)[g]	0.53 (0.05, 0.70)	0.15 (0.02, 0.45)[h]	0.37	**<0.01**
Mixed meals	0.00 (0.00, 0.22)[g]	0.15 (0.00, 0.40)	0.00 (0.00, 0.26)[h]	0.16	0.16 (0.00, 0.61)[g]	0.04 (0.00, 0.60)	0.27 (0.00, 0.59)[h]	0.60	**<0.01**

1.00 = 1 serving. Serving size = 75g vegetables or 150g fruit.
Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance

a-h: values with the same superscript letters are statistically different according to the Bonferroni correction when p <0.05.
*Significance between ethnicities

^Significance within ethnicity
Obesity: BMI ≥30
Overweight: BMI≥25<30
Normal BMI: BMI ≥18.5-≤24.9

Supplementary Results Table 4: Average intake of fruit and/or vegetables serves per mealtime by ethnicity and BMI category

	BMI; Pacific N=142				**BMI; NZE N=161**				
Meal time	**Obese n=75(24.8%)** median (25-75)	**Overweight n=31(10.0%)** median (25-75)	**Healthy BMI n=36(11.9%)** median (25-75)	**p-value^**	**Obese n=71(23.4%)** median (25-75)	**Overweight n=12(3.9%)** median (25-75)	**Healthy BMI n=78(25.7%)** median (25-75)	**p-value^**	**p-value***
Early snack	0.00 (0.00, 0.00)$^{\mathbf{b}\,\underline{zyv}}$	0.00 (0.00, 0.00)$^{\mathbf{b}\,\underline{zyx}}$	0.00 (0.00, 0.00)$^{\underline{zyx}}$	**0.03**	0.00 (0.00, 0.00)$^{\mathbf{zy}}$	0.00 (0.00, 0.00)$^{\underline{zyxwv}}$	0.00 (0.00, 0.00)$^{\underline{zyxw}}$	0.67	0.02
pure	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)		0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)		0.32
part of a mixed meal	0.00 (0.00, 0.00)^{a}	0.00 (0.00, 0.00)^{ab}	0.00 (0.00, 0.00)^{b}		0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)		**<0.01**
Breakfast	0.00 (0.00, 0.38)$^{\mathbf{g}\,\underline{z}}$	0.00 (0.00, 0.42)$^{\underline{ywv}}$	0.08 (0.00, 0.79)$^{\underline{z}}$	0.52	0.46 (0.03, 0.93)$^{\mathbf{g}\,\underline{yx}}$	0.70 (0.06, 1.22)$^{\underline{zy}}$	0.38 (0.00, 1.07)$^{\underline{y}}$	0.81	**<0.01**
pure	0.00 (0.00, 0.31)^{g}	0.00 (0.00, 0.42)	0.04 (0.00, 0.79)		0.45 (0.00, 0.93)^{g}	0.71 (0.06, 1.21)	0.34 (0.00, 1.07)		**<0.01**
part of a mixed meal	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)		0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)		0.23
Morning tea	0.09 (0.00, 0.59)$^{\underline{xwv}}$	0.22 (0.00, 0.60)$^{\underline{xu}}$	0.14 (0.00, 0.50)$^{\underline{y}}$	0.93	0.22 (0.00, 0.52)^{zw}	0.46 (0.03, 1.19)$^{\underline{w}}$	0.26 (0.00, 0.74)$^{\underline{u}}$	0.47	0.31
pure	0.00 (0.00, 0.50)	0.13 (0.00, 0.50)	0.06 (0.00, 0.49)		0.20 (0.00, 0.47)	0.46 (0.03, 1.14)	0.22 (0.00, 0.73)		0.11
part of a mixed meal	0.00 (0.00, 0.00)	0.00 (0.00, 0.11)	0.00 (0.00, 0.00)		0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)		0.57
Lunch	0.29 (0.00, 0.73)$^{\mathbf{g}\,\underline{zyx}}$	0.48 (0.18, 1.31)$^{\underline{xwt}}$	0.55 (1.06, 0.69)$^{\mathbf{h}\,\underline{z}}$	0.10	0.69 (0.40, 1.44)$^{\mathbf{g}\,\underline{yxwv}}$	0.60 (0.35, 0.97)$^{\underline{vu}}$	0.99 (0.46, 1.57)$^{\mathbf{h}\,\underline{zyxw}}$	0.17	**<0.01**
pure	0.19 (0.00, 0.59)^{g}	0.22 (0.20, 0.81)	0.45 (0.01, 0.75)$^{\mathbf{h}}$		0.57 (0.11, 1.21)^{g}	0.40 (0.12, 0.83)	0.79 (0.31, 1.42)^{h}		**<0.01**
part of a mixed meal	0.00 (0.00, 0.13)	0.00 (0.00, 0.30)	0.06 (0.00, 0.20)		0.00 (0.00, 0.25)	0.00 (0.00, 0.16)	0.00 (0.00, 0.28)		0.34
Afternoon tea	0.58 (0.32, 1.38)$^{\underline{zyw}}$	0.48 (0.02, 0.76)$^{\underline{yv}}$	0.41 (0.10, 0.96)$^{\underline{y}}$	0.07	0.35 (0.00, 0.75)$^{\underline{yxwv}}$	0.53 (0.00, 1.19)$^{\underline{x}}$	0.47 (0.14, 1.03)$^{\underline{w}}$	0.23	0.06
pure	0.37 (0.00, 0.78)	0.23 (0.00, 0.69)	0.30 (0.02, 0.59)		0.46 (0.00, 0.96)	0.24 (0.00, 1.25)	0.63 (0.00, 0.99)		0.37
part of a mixed meal	0.12 (0.00, 0.36)^{g}	0.00 (0.00, 0.21)	0.00 (0.00, 0.20)		0.00 (0.00, 0.00)^{g}	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)		**<0.01**
Dinner	0.77 (0.20, 1.89)$^{\mathbf{g}\,\underline{zyx}}$	1.15 (0.58, 1.83)$^{\underline{vus}}$	0.92 (0.37, 1.72)$^{\underline{zyx}}$	0.46	1.63 (1.17, 2.42)$^{\mathbf{g}\,\underline{yxv}}$	1.46 (1.10, 3.18)$^{\underline{zyxwvu}}$	1.94 (1.35, 2.96)$^{\underline{zyxw}}$	0.18	**<0.01**
pure	0.36 (0.00, 1.14)^{g}	0.69 (0.20, 1.30)	0.52 (0.27, 1.01)^{h}		1.37 (0.69, 1.96)^{g}	1.21 (0.56, 2.88)^{e}	1.49 (0.90, 2.54)^{eh}		**<0.01**
part of a mixed meal	0.22 (0.00, 0.44)	0.32 (0.00, 0.70)	0.22 (0.01, 0.45)		0.29 (0.02, 0.63)	0.36 (0.12, 0.68)	0.31 (0.00, 0.54)		0.64
Supper	0.00 (0.00, 0.66)$^{\mathbf{g}\,\underline{y}}$	0.18 (0.00, 0.62)$^{\underline{zts}}$	0.29 (0.00, 0.67)$^{\mathbf{h}\,\underline{x}}$	0.57	0.00 (0.00, 0.00)$^{\mathbf{g}\,\underline{xwv}}$	0.00 (0.00, 0.37)$^{\underline{u}}$	0.00 (0.00, 0.20)$^{\mathbf{h}\,\underline{zyxw}}$	0.15	**<0.01**
pure	0.00 (0.00, 0.47)	0.00 (0.00, 0.22)	0.00 (0.00, 0.42)		0.00 (0.00, 0.00)	0.00 (0.00, 0.37)	0.00 (0.00, 0.10)		0.23
part of a mixed meal	0.00 (0.00, 0.04)^{abg}	0.00 (0.00, 0.24)^{a}	0.00 (0.00, 0.29)^{bh}		0.00 (0.00, 0.00)^{g}	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)h		**<0.01**
p-value	**<0.01**	**<0.01**	**<0.01**		**<0.01**	**<0.01**	**<0.01**		

1.00 = 1 serve. Serving size = 75g vegetables and 150g fruit
Significance tested with Kruskal-Wallis Test; P<0.05 denotes statistical significance
a-h: values with the same superscript letters (row) are statistically different according to the Bonferroni correction when p <0.05.
S-Z: values with the same superscript letters (column) are statistically difference according to the related-samples Friedman's Two-Way Analysis of variance

Obesity: BMI ≥30
Overweight: BMI≥25<30
Healthy BMI: BMI ≥18.5-≤24.9
^: Within ethnicity
**: Between ethnicities*

Supplementary Results Table 5: Diversity of fruit and vegetable intake across seven days by ethnicity

Group	Food	NZE n=161			Pacific n=142			p-value
		Frequency	*Percent of all participants (%)*	*Percent of consumers (%)*	*Frequency*	*Percent of all participants (%)*	*Percent of consumers (%)*	
Citrus fruits			**141 (87.6%)**			**117 (82.4%)**		**0.22**
	Lemon/Lime	86	53.4	61.0	82	57.7	70.0	
	Orange	97	60.2	68.8	62	43.7	53.0	
	Mandarin	77	47.8	54.6	71	50.0	60.7	
	Kiwifruit	53	32.9	37.6	39	27.5	33.3	
Vitamin A rich fruit			**81 (50.3%)**			**80 (56.3%)**		**0.27**
	White Peach	7	4.3	8.6	5	3.5	6.3	
	Yellow Peach	30	18.6	37.0	26	18.3	32.5	
	Mango	44	27.3	54.3	32	22.5	40.0	
	Apricot	14	8.7	17.3	16	11.3	20.0	
	Plum	14	8.7	17.3	16	11.3	20.0	
	Watermelon	37	23.0	45.7	15	10.6	18.8	
	Melon	17	10.6	21.0	10	7.0	12.5	
	Persimmon	6	3.7	7.4	19	13.4	23.8	
	Tamarillo	5	3.1	6.2	7	4.9	8.8	
	Gooseberry	0	0.0	0.0	0	0	0	
Berries			**94 (58.4%)**			**77 (54.2%)**		**0.47**
	Berries	67	41.6	71.3	74	52.1	96.1	
	Strawberry	68	42.2	72.3	31	21.8	40.3	
Other fruit			**153 (95.0%)**			**132 (93.0%)**		**0.46**
	Apple	120	74.5	78.4	107	75.4	81.1	
	Pear	68	42.2	44.4	49	34.5	37.1	
	Grape	72	44.7	47.1	51	35.9	38.6	
	Banana	128	79.5	83.7	115	81.0	87.1	
	Pineapple	53	32.9	34.6	39	27.5	29.5	
	Feijoa	9	5.6	5.9	38	26.8	28.8	
	Guava	5	3.1	3.3	4	2.8	3.0	
	Lychee	5	3.1	3.3	3	2.1	2.3	
	Papaya	9	5.6	5.9	5	3.5	3.8	
	Passionfruit	7	4.3	4.6	4	2.8	3.0	
Allium vegetables			**153 (95.0%)**			**134 (94.4%)**		**0.80**
	Onion	148	91.9	96.7	130	91.5	97.0	
	Spring Onion	81	50.3	52.9	61	43.0	45.5	
	Leek	19	11.8	12.4	21	14.8	15.7	
	Garlic	132	82.0	86.3	114	80.3	85.1	
Cruciferous vegetables			**161 (100%)**			**142 (100%)**		-
	Turnip	2	1.2	1.3	0	0	0	
	Chinese Greens	48	29.8	32.2	45	32.2	35.4	
	Brussel Sprouts	14	8.7	9.4	20	14.1	15.4	
	Cauliflower	85	52.8	57.0	72	50.7	55.4	
	Broccoli	128	79.5	84.9	113	79.6	87.7	
	Red Cabbage	43	26.7	28.9	29	20.4	22.3	

Group	Food	NZE n=161			Pacific n=142			p-value
		Frequency	*Percent of all participants (%)*	*Percent of consumers (%)*	*Frequency*	*Percent of all participants (%)*	*Percent of consumers (%)*	
	Cabbage	91	56.5	61.1	65	45.8	50.8	
Green vitamin a rich vegetables			**151 (93.8%)**			**135 (95.1%)**		**0.62**
	Spinach/Silverbeet	98	60.9	64.9	86	60.6	63.7	
	Puha	1	0.6	0.7	0	0	0	
	Watercress	8	5.0	5.3	7	4.9	5.2	
	Taro Leaves	37	23.0	24.5	13	9.2	9.6	
	Lettuce	138	85.7	91.4	115	81.0	85.2	
	Courgette	48	29.8	31.8	68	47.9	50.4	
Yellow vitamin A rich vegetables			**155 (96.3%)**			**137 (96.5)**		**0.92**
	Carrots	145	90.1	93.5	131	92.3	95.6	
	Pumpkin	69	42.9	44.5	79	55.6	57.7	
	Kumara	91	56.5	58.7	82	57.7	59.9	
	Capsicum	93	57.8	60.0	83	58.5	60.6	
	Red Capsicum	103	64.0	66.5	92	64.8	67.2	
Starchy vegetables			**147 (91.3%)**			**134 (94.4%)**		**0.30**
	Potato	132	82.0	89.9	127	89.4	94.8	
	Taro	33	20.5	22.4	25	17.6	18.7	
	Cassava	42	26.1	28.6	14	9.9	10.4	
	Corn	45	28.0	30.6	61	43.0	45.5	
	Green Banana	39	24.2	26.5	19	13.4	14.2	
	Swede	4	2.5	2.7	4	2.8	3.0	
	Yam	25	15.5	17.0	12	8.5	9.0	
	Parsnip	12	7.5	8.2	18	12.7	13.4	
Vegetables containing starch			**134 (83.2%)**			**112 (78.9%)**		**0.35**
	Squash	19	11.8	14.2	18	12.7	16.1	
	Green Beans	85	52.8	63.4	80	56.3	71.4	
	Peas	90	55.9	67.2	84	59.2	75.0	
	Beetroot	51	31.7	38.1	62	43.7	55.4	
Other vegetables			**149 (92.5%)**			**130 (90.9%)**		**0.30**
	Artichoke	7	4.3	5.2	5	3.5	4.1	
	Eggplant	19	11.8	14.2	12	8.5	9.9	
	Mushroom	97	60.2	72.4	90	63.4	74.4	
	Chilli	72	44.7	53.7	51	35.9	42.1	
	Celery	63	39.1	47.0	62	43.7	51.2	
	Asparagus	26	16.1	19.4	9	6.3	7.4	
	Rhubarb	7	4.3	5.2	5	3.5	4.1	
	Cucumber	118	73.3	79.2	89	62.2	68.5	
Tomatoes								
	Tomatoes	142	88.2	88.2	133	93.7	93.7	

Linear regression separated by ethnicity

Other Results Table 6: Linear Regression of fruit and vegetable serves and BMI and BF% in Pacific

BMI		β	Std error β	95% Cl β	Std'ised β	P-value*
Model 1	Age	0.20	0.10	0.01, 0.39	0.17	**0.04**
				F ratio 4.27 (1 140) Adjusted r^2 0.02 P 0.04		
Model 2	Age	0.24	0.10	0.04, 0.44	0.21	**0.02**
	Deprivation	0.58	0.27	0.04, 1.12	0.18	**0.04**
				F ratio 4.17 (2 137) Adjusted r^2 0.04 P 0.02		
Model 3	Age	0.26	0.11	0.05, 0.47	0.22	**0.02**
	Deprivation	0.58	0.27	0.04, 1.13	0.18	**0.04**
	Vegetables Serves	-0.24	0.48	-1.18, 0.70	-0.05	0.61
				F ratio 2.85 (3 136) Adjusted r^2 0.04 P 0.04		
Model 4	Age	0.26	0.11	0.05, 0.47	0.22	**0.02**
	Deprivation	0.58	0.28	0.04, 1.13	0.18	**0.04**
	Vegetable Serves	-0.24	0.48	-1.19, 0.71	-0.05	0.62
	Fruit Serves	-0.02	0.45	-0.90, 0.87	-0.01	0.97
				F ratio 2.12 (4 125) Adjusted r^2 0.03 P 0.08		

BF%		β	Std error β	95% Cl β	Std'ised β	P-value*
Model 1	Age	0.25	0.12	0.02, 0.48	0.18	**0.04**
				F ratio 4.55 (1 139) Adjusted r^2 0.03 P 0.04		
Model 2	Age	0.29	0.12	0.05, 0.53	0.21	**0.02**
	Deprivation	0.53	0.33	-0.14, 1.19	0.14	0.12
				F ratio 3.39 (2 136) Adjusted r^2 0.03 P 0.04		
Model 3	Age	0.33	0.13	0.08, 0.59	0.24	**0.01**
	Deprivation	0.54	0.33	-0.12, 1.20	0.14	0.12
	Vegetable Serves	-0.61	0.58	-1.75, 0.53	-0.09	0.29
				F ratio 2.64 (3 135) Adjusted r^2 0.03 P 0.05		
Model 4	Age	0.33	0.13	0.08, 0.59	0.24	**0.01**
	Deprivation	0.54	0.34	-0.01, 1.21	0.14	0.11
	Vegetable Serves	-0.61	0.58	-1.77, 0.55	-0.09	0.30
	Fruit Serves	-0.02	0.54	-1.09, 1.06	-0.01	0.98
				F ratio 1.97 (4 134) Adjusted r^2 0.03 P 0.10		

BMI: Body Mass Index
BF%: Body Fat Percentage

Other Results Table 7: Linear Regression of fruit and vegetable serves and BMI and BF% in NZE

BMI		**β**	**Std error β**	**95% Cl β**	**Std'ised β**	**P-value***
Model 1	Age	0.24	0.07	0.11, 0.38	0.27	**<0.01**
		F ratio 12.2 (1 159) Adjusted r^2 0.07 P <0.01				
Model 2	Age	0.26	0.07	0.12, 0.39	0.28	**<0.01**
	Deprivation	0.42	0.20	0.02, 0.81	0.16	**0.04**
		F ratio 8.20 (2 157) Adjusted r^2 0.08 P <0.01				
Model 3	Age	0.25	0.07	0.12, 0.38	0.28	**<0.01**
	Deprivation	0.40	0.20	0.02, 0.79	0.15	**0.04**
	Vegetable Serves	-0.83	0.25	-1.32, -0.35	-0.25	**<0.01**
		F ratio 9.65 (3 156) Adjusted r^2 0.14 P <0.01				
Model 4	Age	0.24	0.08	0.11, 0.37	0.27	**<0.01**
	Deprivation	0.42	0.20	0.03, 0.80	0.16	**0.04**
	Vegetable Serves	-0.75	0.26	-1.26, -0.24	-0.22	**<0.01**
	Fruit Serves	-0.43	0.39	-1.20, 0.35	-0.08	0.28
		F ratio 7.54 (4 155) Adjusted r^2 0.14 P <0.01				

BF%		**β**	**Std error β**	**95% Cl β**	**Std'ised β**	**P-value***
Model 1	Age	0.32	0.11	0.10	0.22	**<0.01**
		F ratio 7.89 (1 159) Adjusted r^2 0.04 P <0.01				
Model 2	Age	0.34	0.11	0.12, 0.57	0.23	**<0.01**
	Deprivation	0.73	0.33	0.07, 1.38	0.17	**0.03**
		F ratio 6.19 (2 157) Adjusted r^2 0.06 P <0.01				
Model 3	Age	0.33	0.11	0.11	0.22	**<0.01**
	Deprivation	0.71	0.32	0.07	0.17	**0.03**
	Vegetable Serves	-1.40	0.41	-2.20	-0.26	**<0.01**
		F ratio 8.36 (3 156) Adjusted r^2 0.12 P <0.01				
Model 4	Age	0.31	0.11	0.10, 0.53	0.21	**<0.01**
	Deprivation	0.74	0.32	0.10, 1.27	0.17	**0.02**
	Vegetable Serves	-1.18	0.42	-2.02, -0.34	-0.22	**<0.01**

BF%		β	Std error β	95% Cl β	Std'ised β	P-value*
	Fruit Serves	-1.11	0.64	-2.38, 0.17	-0.13	0.09
		F ratio 7.09 (4 155) Adjusted r^2 0.13 P <0.01				

BMI: Body Mass Index
BF%: Body Fat Percentage