Exploring the dietary intake and eating patterns of New Zealand European women aged 16-45 years

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Abstract

Background/Aim: Analysing dietary intakes gives insight to an individual or groups nutritional status. Investigating dietary patterns provides an alternative measure to identify combinations of foods that are related to excess adiposity. The aim of this study is to investigate dietary intakes and eating patterns of New Zealand European (NZE) women with different body composition profiles, participating in the women's EXPLORE (Examining the Predictors Linking Obesity Related Elements) study.

Methods: Post-menarche, pre-menopausal NZE women (16-45 years) (n=231) completed a validated 220-item, self-administrated, semi-quantitative food frequency questionnaire (FFQ) assessing dietary intake over the previous month. Quetelet's body mass index (BMI) was calculated (kg/m^2) from height and weight measurements; body fat percentage (BF%) was measured using air displacement plethysmography (BodPod). Participants were categorised into one of three body composition profile (BCP) groups: normal BMI (18.5-24.9 kg/m^2), normal BF% (≥22%, <30%) (HH); normal BMI, high BF% (≥30%)(NH); high BMI (≥25 kg/m^2), high BF% (HH). Dietary intakes, macronutrient profiles and diet quality for the total NZE women and the BCP groups were analysed. Dietary patterns were identified using principal component factor analysis and broken into tertiles (T1, T2, T3). Associations between dietary patterns, age, BMI and BF% were investigated.

Results: Many NZE women consumed insufficient vitamin D (55%), iron (82%), calcium (28.5%), folate (48%) and dietary fibre (28%) intakes. Mean±SD percentage of energy intake for carbohydrate (41.9±7%) was below and for saturated fat (13.9±3.5%) above the acceptable macronutrient distribution range for the total NZE women. The top 40 food items consumed by the NZE women included water, bread, tea, coffee, milk and yoghurt. Diet soft drinks were only present in the HH BCP group. Four dietary patterns were identified: P1: 'Snacking' pattern; P2: 'Energy-dense meat' pattern; P3: 'Fruit and vegetable' pattern; P4: 'Healthy' pattern, which explained 6.9, 6.8, 5.6 and 4.8% of variation in food intake, respectively. Younger (16-24 years) (P=0.035) and overweight (26.4±26.7kg/m^2) (P=0.036) women were significantly associated with P2, loading highly in T3. No significant associations were found with BF%. Intakes of vitamin A, E, D, and zinc were comparable between normal BF% and high BF% BCP groups.

Conclusion: NZE women consume inadequate iron, vitamin D, folate, calcium and dietary fibre intakes irrespective of body fatness. Dietary patterns of NZE women can be linked to specific body compositions, specifically, women with a high BMI high BF% were associated with a diet characteristic of meat, high fat sauces, puddings and fried foods. Regardless of BF%, NZE women follow a diet low in carbohydrate and high in saturated fat. Diet quality of vitamin A, D, E, iron, and zinc in women with a high BF% is comparable to that of women with normal BF%'s showing good diet quality. Targeted interventions can be developed based on these findings to increase nutrient intakes of NZE women and improve the health status of those with excess adiposity.

Key words: Dietary intake, dietary patterns, factor analysis, food frequency questionnaire

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Table of Contents

List of Tables

List of Figures

List of Appendices

Abbreviation List

ADP	Air Displacement Plethysmography
BCP group	Body Composition Profile Group
BF%	Body Fat Percentage
BP	Blood Pressure
BMR	Basal Metabolic Rate
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
CHD	Coronary Heart Disease
CVD	Cardiovascular Disease
CHO	Carbohydrate
DASH	Dietary Approach to Stop Hypertension
DQ	Diet Quality
DXA	Dual Energy X-ray Absorptiometry
EXPLORE study	Examining Predictors Linking Obesity Related Elements
FFQ	Food Frequency Questionnaire
GI	Glycaemic Index
GL	Glycaemic Load
HC	Hip Circumference

HFCS	High Fructose Corn Syrup
HH	High Body Mass Index; High Body Fat Percentage
HN	High Body Mass Index; Normal Body Fat Percentage
KMO	Kaiser-Meyer-Olkin
LDL-c	Low Density Lipoprotein Cholesterol
MAMC	Mid Arm Muscle Circumference
NN	Normal Body Mass Index; Normal Body Fat Percentage
NH	Normal Body Mass Index; High Body Fat Percentage
NL	Normal Body Mass Index; Low Body Fat Percentage
NZE	New Zealand European
NZWFFQ	New Zealand Women's Food Frequency Questionnaire
PCA	Principal Component Analysis
SSB	Sugar- Sweetened Beverage
T2DM	Type 2 Diabetes Mellitus
TC	Total Cholesterol
WHO	World Health Organisation
WC	Waist Circumference
W:H ratio	Waist-to-Hip Ratio

Chapter 1 Introduction

1.1 Background

The 2008/09 New Zealand Adult Nutrition Survey identified 32.8% and 27.8% of females over the age of 15 years were overweight and obese, respectively (University of Otago and Ministry of Health, 2011). Prevalence of obesity has significantly risen since 1997 (females 20.6%) in both New Zealand and worldwide (University of Otago and Ministry of Health, 2011, World Health Organisation, 2015). It is well-established that obesity is a major risk factor for many health conditions including but not limited to cardiovascular disease, type 2 diabetes, hypertension, insulin resistance, dyslipidaemia, osteoarthritis, sleep apnoea, psychological and social problems and some cancers (University of Otago and Ministry of Health, 2011, World Health Organisation, 2015, Stein, 2004, Oliveros, 2014, Poirier *et al.*, 2006, Pi-Sunyer, 2002, McMichael, 2008).

To determine obesity, Body Mass Index (BMI) is calculated. This is an easy non-invasive calculation using height (m) and weight (kg) measurements. According to the Ministry of Health overweight and obesity are defined as having a BMI score between 25 kg/m^2 and 29.9 kg/m^2, and greater than 30 kg/m^2, respectively (Ministry of Health, 2008). Although routinely used in epidemiological studies and by health professionals, BMI is an imperfect measure of body fatness due to indirectly measuring body composition and assuming excess body fat to be present in overweight and obese individuals (University of Otago and Ministry of Health, 2011). It speculates that at any given height, a higher weight correlates to a larger body fat percentage (BF%) and consequently a higher risk of morbidity and mortality (Gallagher *et al.*, 2000). The BMI calculation has good specificity but poor sensitivity and as such, some individuals for example athletes, who have a high lean muscle mass are incorrectly classed as overweight, whereas others are classed as having a normal BMI where a large BF% may be present (Gallagher *et al.*, 2000, Romero-Corral *et al.*, 2008a). In this case, large body fatness is indicated as greater than 30% (Oliveros, 2014, De Lorenzo *et al.*, 2006). It is estimated that more than half of individuals are misclassified, and thus it is important to determine how we classify them into the correct category to accurately acknowledge their body fatness and consequently what, if any specific dietary recommendations we should be advising (Gallagher *et al.*, 2000, Oliveros, 2014).

As a more accurate measure of body composition, the emerging gold standard method of air displacement plethysmography (ADP) can be used (Fields *et al.*, 2002, Collins and McCarthy, 2003). This method commercially known as the BODPOD calculates whole body volume and density which is then used to determine the percentage proportions of body fat and lean mass (Lowry and Tomiyama, 2015). It is a quick, safe, non-invasive method which provides highly reproducible results and is accommodating for all participants (e.g. children, adults, elderly, disabled, overweight, and obese) (Fields *et al.*, 2002, Lowry and Tomiyama, 2015, Ginde *et al.*, 2005). As a result, compliance and acceptability of the method is high due to minimal participant burden (Collins and McCarthy, 2003). The highly accurate and precise body composition results can be compared to the individuals BMI, which enables us to identify those who have a normal BMI with either a high or normal BF% (Collins and McCarthy, 2003, Fields *et al.*, 2002, Lowry and Tomiyama, 2015). Reviewing this in combination with both lifestyle and dietary factors allows the chronic disease risk to be assessed.

Body composition is influenced by lifestyle and dietary factors. The types of foods we habitually consume impact the ratio of fat mass to lean muscle mass in the body. Although many studies have investigated the effects of specific macronutrients on body composition, dietary patterns have had less attention (McNaughton *et al.*, 2007, McNaughton *et al.*, 2008, Hu, 2002). Assessing dietary patterns and diet quality addresses the diet as a whole and are two important determinants to consider.

Dietary patterns

The western dietary pattern has been associated with a higher BMI and an increased risk of cardiovascular disease, type 2 diabetes and cancer (Drewnowski, 2004, Schulze, 2006, Cha *et al.*, 2012, Rodríguez-Monforte *et al.*, 2015). It is characterised by a habitual intake of high glycaemic index (GI), refined grains, breads and cereals, red and processed meats, frequent consumption of fast-food, sugar-sweetened beverages (SSB), sweets and desserts (Schulze, 2006, Murtaugh *et al.*, 2007, Hu, 2002). New Zealanders adherence to this diet is increasing and as a consequence the prevalence of chronic disease is rising (Cha *et al.*, 2012).

Specific components of the western diet such as fast-food and SSB consumption are important factors of increased body fatness (Nicklas, 2001, Te Morenga *et al.*, 2013). The frequent consumption of SSB has consistently been associated with excess caloric consumption, increased body fatness and a diet lacking in essential nutrients (Nikpartow *et al.*, 2012, Schulze, 2004, DiMeglio, 2000, Johnson *et al.*, 2009, Tordoff and Alleva, 1990, Vartanian *et al.*, 2007). Individuals who consume primarily SSB have been found to have an 85% increased risk

of being overweight, and twice as likely to be overweight or obese compared to individuals who drink a combination of beverages (Nikpartow *et al.*, 2012). It is thought that the energy provided as a liquid carbohydrate is not compensated for throughout the day and this promotes a positive energy balance compared to consuming carbohydrate in a solid food form (DiMeglio, 2000, Mourao, 2007). Further to this, diet SSB have also been associated with an increased BMI due to increasing the desire to eat thus leading to a positive energy balance (Liebman *et al.*, 2006).

A positive energy balance can also be linked with fast-food consumption. Dietary patterns characterised by regular fast-food intakes have been shown to significantly increase the risk of obesity, especially in women (Liebman *et al.*, 2006, French, 2000, Schroeder *et al.*, 2007). Fast-food outlets are significantly increasing and are popular choices by many due to their convenience (Rosenheck, 2008). The food options available are typically energy-dense, nutrient poor, low in fibre, high in saturated fatty acids, trans fatty acids and salt, and served in excessive portion sizes (Rosenheck, 2008). Frequent consumption increases the energy and fat content of a diet and subsequently leads to increased body fatness and an increased BMI (Liebman *et al.*, 2006, French, 2000, Bowman and Vinyard, 2004). This is true, especially for women who have lower energy requirements compared to men and in conjunction with the low satiety factor of fast-food, the ability to overeat is enhanced (Liebman *et al.*, 2006). Although a strong relationship between obesity and fast-food consumption has been well documented (Prentice and Jebb, 2003, Rosenheck, 2008, Pereira *et al.*, 2005, Bowman and Vinyard, 2004), there is still controversy surrounding the causal relationship with some studies, questioning the role of physical inactivity (Rosenheck, 2008).

In comparison, a diet composed of fruit, vegetables, whole grain bread and cereals, lean unprocessed meats, poultry, fish and low fat dairy products is independently associated with a higher dietary adequacy, lower BMI, and lower waist circumference, thus reducing the risk of excess adiposity and consequent chronic disease (Schulze, 2006, Murtaugh *et al.*, 2007, He, 2004, Newby *et al.*, 2003, Liu *et al.*, 2003).

Diet quality

Diet quality can be referred to as dietary adequacy; the extent to which ones diet fits within the acceptable macronutrient distribution ranges (AMDR) and meets the recommended daily intake (RDI) for all micronutrients (Steyn, 2013). Dietary adequacy can be determined by an individual's dietary intake and eating patterns, which influence macronutrient distribution, body composition and health outcomes (figure 1.1) (Wirt and Collins, 2009). Women with poor

diet quality have been shown to consume diets lower in carbohydrates and micronutrients and higher in saturated fat and alcohol. These women are also at a higher risk of obesity (Wolongevicz, 2010).

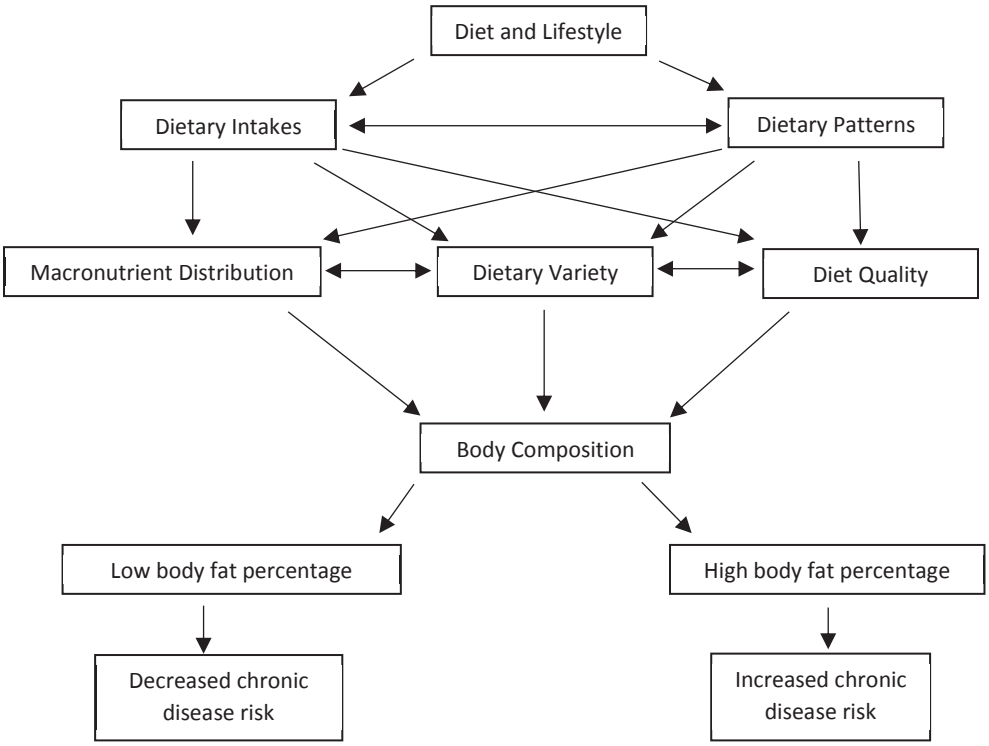


Figure 1.1 The relationship between diet, body fat percentage and health outcomes.

Studies investigating the macronutrient distribution ranges have found that when the BF% of women increased, the percentage of fat derived from their diet also increased (35%) and the carbohydrate content decreased (46%) compared to lean individuals (29% and 53%, respectively) (Miller *et al.*, 1990). Furthermore, compliance to dietary recommendations is low in obese individuals with less than 10% complying with the daily fruit and vegetable recommendations (De Abreu, 2013). This suggests that the dietary macronutrient composition may be an important determinant in dietary adequacy and resulting body composition.

Dietary intakes in obese individuals have routinely shown to be inadequate. Individuals with excess body fat consistently have a low quality diet, compared to those within the healthy BMI range who generally have high dietary adequacy (Wolongevicz, 2010). Micronutrients such as vitamin A, zinc, calcium and iron have previously been identified as low or deficient in individuals with excess body fat (Eckhardt, 2008, García *et al.*, 2009, Tidwell and Valliant,

2011). Study results have indicated that obesity may exacerbate dietary inadequacy or cause an adequate diet to become inadequate (Chai, 2010). When adjusted for nutrient density, obese individuals had a significantly lower serum level of 25-hydroxyvitamin D and carotenoids particularly pro-vitamin A compared to the normal weight women (Chai, 2010). This difference is thought to be due to the increased chronic inflammation seen in those with excess body fat which may lead to a higher requirement of some nutrients (Oliveros, 2014, De Lorenzo *et al.*, 2007). Low micronutrient status may contribute to the development of obesity and thus dietary recommendations different to that of individuals with healthy BF%'s may be required.

1.2 Purpose of the Study

Obesity is a multi-factorial worldwide health problem where its prevalence is increasing at an alarming rate. The dietary intake of individuals is a significant factor in determining their body composition and while obesity is important to consider, the dietary intakes and how they influence body fat content in women may be of value in assessing an individual's risk of chronic disease. It may be that those who have a normal BMI with high body fat require different dietary advice to those of normal BMI, normal body fat or those of high BMI, high body fat. While efforts have been made to address the role of dietary intake on BMI values, few attempts have investigated how the current dietary intakes and patterns of women relate to BF%, their subsequent BMI's and how we can tailor our dietary advice according to these body fat profiles. Investigating these factors will enable targeted interventions to be developed in an attempt to improve the morbidity and mortality outcomes in these women.

1.2.1 Aim

To explore the dietary intake and eating patterns of New Zealand European women with predetermined body composition profiles aged 16-45 years.

1.2.2 Objectives

1. To explore the dietary intakes of women in the different body composition profile (BCP) groups.
2. To identify the eating patterns which are the strongest predictors of increased body fat.
3. To explore the differences in the macronutrient profile intakes in women with different body composition profiles.
4. To explore the micronutrient intake in each BCP group and compare the differences in diet quality.

1.3 Thesis Structure

This study had been structured into six sections. Chapter 1 introduces the research and highlights its importance. Chapter 2 is a review of the literature, including sections on obesity and health, dietary patterns, macronutrient distribution, diet quality, and assessing dietary intake. Chapter 3 outlines the methods and materials used in this study. This is then followed by chapter 4 which presents the results of the study. Chapter 5 discussed the findings of this study. Finally, chapter 6 draws conclusions and highlights the study strengths, limitations and recommendations for future research.

1.4 Researcher's Contributions to the Study

Table 1.2 Researchers contributions to the study.

Researchers	Contributions to the thesis
Jenna Schrijvers	Main researcher, recruited and screened participants, supervised participant testing, data entry and analysis, conducted statistical analysis, interpretation and discussion of results, author of thesis
A/Prof Rozanne Kruger	Main academic supervisor, primary investigator of the EXPLORE study, application for ethics, development of study design, data analysis, and interpretation of results, thesis revision and approval
A/Prof Sarah McNaughton	Academic co-supervisor, advised and checked statistical analysis, interpretation of methods and results, reviewed thesis
Dr Kathryn Beck	Academic co-supervisor, advised on data analysis
Zara Houston, Chelsea Symons, Alex Lawn	Assistance with data entry of the NZWFFQ
Wendy O'Brien, Shakeela Jayasinghe	Coordination of participant recruitment, screening and testing
Maria Casale, Andrea Fenner, Zara Houston, Adrianna Hepburn, Sarah Philipsen, Rozanne Kruger	Recruitment and screening of participants
Pam Von Hurst, Cathryn Conlon, Kathryn Beck, Richard Swift, Owen Mugridge, Maria Casale, Andrea Fenner, Adrianna Hepburn, Sarah Philipsen, Rozanne Kruger	Facilitated testing of the participants which included eight stations: health screening questionnaire, blood sample, blood pressure, BODPOD, DEXA scan, three dietary questionnaires (NZWFFQ, eating habits, eating behaviour) *(Note: participants were recruited as part of the wider EXPLORE study and not all data collected is used within this thesis)*
PC Tong	Assistance with equipment for data collection

NZWFFQ = New Zealand Women's Food Frequency Questionnaire;
DEXA scan = Dual Energy X-ray Absorptiometry

Chapter 2 Literature Review

2.1 Obesity and Health

2.1.1 Obesity definition

Overweight and obesity are defined as the presence of abnormal or excessive body fat which poses a health risk to the individual (World Health Organisation, 2014b). In general, a good indicator of obesity is the Body Mass Index (BMI), defined by using weight (kg) divided by height (m) squared (kg/m^2). Individuals are classified into one of four categories: underweight (< 18.50 kg/m^2), normal weight (18.50-24.99 kg/m^2), overweight (25.00–29.99 kg/m^2), and obese (≥ 30.00 kg/m^2) (World Health Organisation, 2014b). A BMI greater than 25.0 kg/m^2 predisposes the individual to chronic disease, including diabetes, hypertension, dyslipidaemia, stroke and cardiovascular disease (World Health Organisation, 2014b). Overweight and obesity are the leading causes of death in the world with around 3.4 million adults dying each year due to complications associated with excessive body fat (World Health Organisation, 2014b). Globally in 2014, 1.4 billion adults (39%) over 18 years old were classified as overweight and of these, 600 million (13%) were obese (World Health Organisation, 2015).

2.1.2 Obesity prevalence in New Zealand

In New Zealand the 2012/13 National Health Survey identified 31.3% of adults over the age of 15 years as obese and a further 34% as overweight (Ministry of Health, 2014c). Specifically in New Zealand females, there has been a progressive increase in the prevalence of obesity (Ministry of Health, 2014c, University of Otago and Ministry of Health, 2011). An increase of both BMI and obesity prevalence was seen in the New Zealand European women and the total New Zealand population from 2006 to 2013/14. Although the percentage of overweight individuals decreased in both groups, this indicates an increase in the prevalence of significant excess adiposity in the New Zealand population (table 2.1).

Table 2.1 Mean BMI and prevalence of overweight and obesity in New Zealand European females and the total population from 2006/07 to 2013/14 (Ministry of Health, 2014b).

Year	New Zealand European women			Total New Zealand population		
	Mean BMI (kg/m^2)	Overweight (%)	Obese (%)	Mean BMI (kg/m^2)	Overweight (%)	Obese (%)
2006/07	26.9 (26.7-27.2)	32.2 (30.7-33.8)	24.6 (22.9-26.4)	27.4 (27.3-27.5)	36.0 (35.0-36.9)	26.5 (25.5-27.5)
2011/12	27.2 (27.0-27.5)	32.9 (31.0-34.9)	26.2 (24.5-28.0)	27.7 (27.5-27.8)	35.4 (34.4-36.4)	28.5 (27.3-29.8)
2012/13	27.5 (27.3-27.7)	31.7 (30.0-33.5)	28.7 (27.2-30.3)	27.9 (27.7-28.0)	34.1 (32.8-35.4)	30.6 (29.5-31.7)
2013/14	27.5 (27.2-27.7)	31.3 (29.7-32.8)	27.5 (25.9-29.1)	27.9 (27.8-28.1)	35.0 (33.9-36.1)	29.9 (28.9-30.9)

BMI = Body mass index;
[a] = Unadjusted mean BMI (95% confidence interval);
[b] = Unadjusted prevalence percentage (95% confidence interval)

2.1.3 Causes of obesity

The aetiology of obesity is varied and complex. The alleged fundamental cause is energy imbalance, where the amount of energy consumed exceeds that which is expended over several months or years (Stein, 2004). Factors such as genetics, age, sex, hormones and other individualised features influence the risk of fat deposition, nevertheless the rapid increase in obesity prevalence suggests it is how the individual reacts to the environment which predicts excess adiposity (Caterson and Gill, 2002, Stein, 2004). The socio-ecological model is a theoretical framework which explains the complex interwoven relationship between environmental factors and obesity in developed countries (figure 2.1) (Blanchard, 2005). Intra and interpersonal factors such as a sedentary lifestyle, energy-dense nutrient-poor food choices (e.g. sugar-sweetened beverages (SSB) and fast-food), large portion sizes along with heavy marketing from food companies all play a part in the rising obesity levels (Swinburn, 2004).

Figure 2.1 The Socio-Ecological Model of factors influencing increased adiposity (Fitzgerald, 2009).

Today, constant changes in the physical, socio-cultural, economic and political environments make it easy to constantly be in a positive energy balance (figure 2.1) (Caterson and Gill, 2002). Modernisation and economic restructuring such as changes in transportation, energy efficient machinery, and increasing urbanisation contribute to the increased availability, variety and consumption of energy-dense foods as well as the increasingly sedentary lifestyles of many individuals (World Health Organisation, 2014b, James *et al.*, 2004, Swinburn, 2004, Caterson and Gill, 2002, Stein, 2004). Advances in technology mean that machines have replaced what once were labour intensive jobs, leaving a sedentary desk job in its place. Domestic tasks such as grocery shopping have been replaced with the internet or smart phone applications, where food can be ordered and delivered straight to your door. This replaces many tasks contributing to our daily incidental physical activity levels and although many of these may indeed save us time, this time is not being put to good use and we are now more sedentary than ever (Caterson and Gill, 2002, Stein, 2004).

In parallel to this, advances in technology have also contributed to increased production of highly processed convenience foods designed to save us even more time. These products are often cheap, readily available, energy-dense and high in fat, salt and sugar; replacing the more traditional diet of what once was high in micronutrients, complex carbohydrates and fibre (Swinburn, 2004). These products in conjunction with cheap sugar sweetened beverages (SSB) and readily available fast-food largely contribute to the increase in obesity rates seen in New Zealand and around the world (Caterson and Gill, 2002).

Additionally, the marketing of these convenience foods is frequently targeted at young adults (Utter *et al.*, 2006). Typically during early adulthood, family influence on dietary habits is

reduced, where individuals start making their own food choices (Demory-Luce *et al.*, 2004). Young adults often move out of home to get further education, travel overseas or obtain additional life skills through flatting. During this time individual eating and lifestyle habits are created, therefore if healthy eating habits are not maintained or adopted, this is likely to contribute to increased adiposity in later adulthood (McNaughton *et al.*, 2008).

2.1.4 Obesity and chronic disease

In 2001, 60% of the 56.5 million deaths in the world were caused by chronic disease, with cardiovascular disease (CVD) contributing to almost half, and obesity and diabetes following close behind (World Health Organisation, 2003). Obesity is one of the most modifiable risk factors in the prevention of chronic disease, yet it is also one of the most common nutritional disorders in the developed world, and is becoming increasingly prevalent in developing countries alongside that of undernutrition (James *et al.*, 2004). The World Health Organisation (WHO) predicts that chronic disease will contribute to almost three quarters of all deaths worldwide by 2020 (World Health Organisation, 2003).

Vast amounts of literature have documented the increased risk associated with obesity, particularly abdominal obesity and the development of chronic diseases (figure 2.2) which include but are not limited to CVD, type 2 diabetes, hypertension, insulin resistance, dyslipidaemia, osteoarthritis, sleep apnoea, metabolic syndrome, and some cancers (University of Otago and Ministry of Health, 2011, Nicklas, 2001, Guh, 2009, Kannel *et al.*, 1996, Poirier *et al.*, 2006, Schenck-Gustafsson, 2009, Oliveros, 2014, McMichael, 2008).

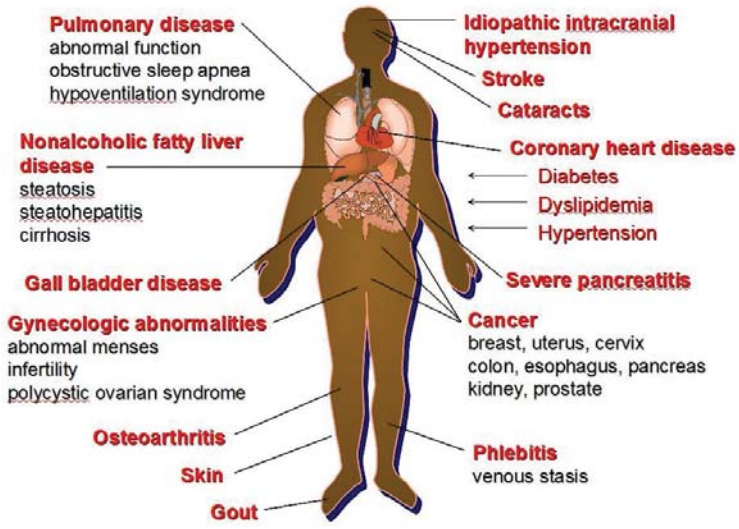


Figure 2.2 The medical complications associated with obesity (Mahan, 2012).

As adiposity increases, many individuals develop more than one of these diseases and thus are particularly susceptible to the metabolic syndrome (James *et al.*, 2004). An independent positive correlation between weight and coronary heart disease (CHD), stroke, congestive heart failure and CVD in women has been found, and those that are overweight by at least 30% are thought to have a stroke risk four times that of their leaner counterparts (Hubert, 1983, Kannel *et al.*, 1996). In addition, weight gain during adulthood is thought to increase the risk of CVD independent of initial weight or other risk factors that may be present (Hubert, 1983). Manson *et al* (1990) reported women to be two to five times more likely to develop hypertension, diabetes, hyperlipidaemia and CHD as adiposity increased with age. This was at least double the risk found in their leaner counterparts. Likewise, women who were moderately overweight or obese (BMI 25-30 kg/m^2) had an 80% increased risk of developing CHD compared to their leaner counterparts (Manson, 1990). Conversely, weight loss has been found to improve or prevent chronic disease associated with excess body fat (Poirier *et al.*, 2006, Klein *et al.*, 2004). A five to 10% loss of body weight significantly improves CVD risk factors, with larger weight loss increasing these benefits (Wing *et al.*, 2011).

2.1.5 Assessing body fatness

Body mass index was first presented in the mid nineteenth century by Adolphus Quetelet based on the observation that body weight was proportional to the squared height in adults with normal body fat (Romero-Corral *et al.*, 2008b). It is the most widely used indicator to quickly identify an individual as overweight or obese, where excess body fat is assumed to be present (table 2.2) (Caterson and Gill, 2002).

Table 2.2 Body Mass Index (BMI) classification (World Health Organisation, 2014a, Obesity Education Initiative Expert Panel on the Identification, 1998).

Classification	**BMI (kg/m^2)**
Underweight	< 18.50
Normal weight	18.50 – 24.99
Overweight	25.00 – 29.99
Obese	≥ 30.00
- Obese class I	30.00 – 34.99
- Obese class II	35.00 – 39.99
- Obese class III	≥ 40

Although BMI is routinely used in many epidemiological studies and by health professionals, it is an imperfect measure of body fatness. The major assumption of the BMI guidelines is that at any given height, a higher weight correlates to a larger BF% and consequently a higher risk of morbidity and mortality (Flegal *et al.*, 2009). Some individuals who are overweight do not have excess adiposity, and in reverse those who have a normal BMI may have a high percentage of hidden body fat (Gallagher *et al.*, 2000). This is the main limitation of BMI; its inability to differentiate between lean muscle mass and fat mass (Oliveros, 2014). For example, an individual with a normal lean and healthy BF% and an individual who has a low lean mass with a high BF% may both have a BMI within the healthy range, however they have different susceptibility to disease risk. The latter individual may have a greater unidentified risk of morbidity and individuals such as these commonly present with metabolic dysregulation, thus BMI can be considered a crude measure of an individual's body fatness (Oliveros, 2014).

Body fat percentage is another way to identify obesity. Although less practical to determine, its accuracy allows us to better identify true excess adiposity, with a BF% greater than 30% correlating to obesity in women (table 2.3) (Oliveros, 2014, De Lorenzo *et al.*, 2006).

Table 2.3 Body fat percentage (BF%) categories for women over 18 years of age (Life Measurement Inc, 2005).

Body fat classification	**BF% (women)**	**Explanation**
High body fat (risky)	> 40%	Body fat needs to be lowered
Excess fat	31 – 40%	Excess body fat is present
Moderately lean	23 - 30%	Acceptable range for good health
Lean	19 – 22%	In range for excellent health and longevity
Ultra-lean	15 – 18%	Body fat levels found in elite athletes
Low body fat (risky)	< 15%	Body fat needs to be increased

Applies to women over 18 years of age

Commonly used methods to assess body composition include underwater weighing, skinfolds, dual x-ray absorptiometry and bio-electrical impedance. Their strengths and weaknesses are outlined in table 2.4.

Table 2.4. Strengths and weaknesses of the main body composition assessment methods (Lee, 2010, Gibson, 2005)

Body composition assessment method	Strengths	Weaknesses	Assumptions
Underwater weighing	• Gold standard for determining body density and body fat • Highly accurate	• Impractical for a large sample size • Subject must be willing to be submerged underwater • Not suitable for children, the sick or elderly • High degree of subject cooperation required • Special equipment required • Expensive	• The fat-free compartment has a constant density
Skinfolds	• Equipment is inexpensive and portable • Measurements are quick and easily obtained	• A trained researcher is required to administer • Strict adherence to standardised techniques are required • Poor repeatability	• Thickness of subcutaneous adipose tissue reflects a constant proportion of total body fat • Skinfold sites selected for measurement represent average thickness of the entire subcutaneous adipose tissue.
Dual x-ray absorptiometry (DEXA)	• Highly precise • Fast and safe • Low participant burden • Requires little cooperation from patients • Can be used for the old and sick • Results highly correlated to underwater weighing	• Cannot be performed on pregnant women due to radiation • Differences in hydration and the presence of bone or calcified tissues may affect results	• Hydration of fat free mass remains constant
Bio-electrical impedance (BIA)	• Safe • Convenient • Portable • Fast • Non-invasive	• Expensive to purchase • Dehydration can result in overestimation of fat mass • Not as accurate as other methods	• Assumes subjects are normally hydrated
Air displacement plethysmography	• Highly accurate • Good repeatability	• Subject must wear tight clothing and be	• Fat free tissue has a constant density

Body composition assessment method	Strengths	Weaknesses	Assumptions
(ADP) (BODPOD)	• Quick and easy • Can be used for children, adults, elderly and the disabled • Can be used for large sample sizes	comfortable in confined spaces • Not portable	

Romero-Corral *et al* (2008b) investigated the validity of BMI in relation to an individual's body composition and found that more than half of the participants with a BF% relating to obesity were not classified as overweight or obese using BMI as an indicator, while greater than 50% of individuals with excess body fat were classed as having a normal body weight (Romero-Corral *et al.*, 2008b). Confirmation of this is provided by Frankenfield *et al* (2001) who found that 46% of women identified as obese through bioelectrical impedance were not classified as obese using the BMI calculation. It has been suggested that using BMI with those who have a normal body weight is limited because it does not take into consideration differences in body fat and lean muscle mass (Romero-Corral *et al.*, 2008b). This indicates that the current obesity epidemic may in fact be larger than once thought, with many normal weight individuals carrying hidden body fat, increasing susceptibility to chronic disease.

2.2 Dietary Patterns

Nutritional epidemiology has traditionally focused on the effects of specific nutrients and foods on health. This approach requires researchers to distinguish the effects of one nutrient from another which is difficult due to complex nutrient combinations within foods (Schulze *et al.*, 2003). Although still an important part of research, large randomised controlled trials have been unsuccessful in showing the predicted health outcomes of individual nutrients (Jacques and Tucker, 2001). Recently, dietary patterns have emerged as a more comprehensive way to assess disease risk in relation to overall eating patterns (Mishra, 2006, McNaughton *et al.*, 2007). This approach recognises that nutrients and foods are consumed in combination with each other, rather than in isolation (Newby *et al.*, 2003, Hu, 2002, Hu *et al.*, 1999, Smith *et al.*, 2011, Schulze *et al.*, 2003, Mishra *et al.*, 2010). Foods have different nutrient compositions and the relationship between nutrients and different foods is an important determinant of disease risk. Particular combinations of foods are likely to be stronger predictors of health compared to considering only one nutrient in the diet (Michels, 2005). For example, a dietary pattern consisting of refined grains, high fat and high added sugar foods may elicit different health outcomes compared to a diet high in fruit, vegetables and whole grains. Assessing specific

dietary patterns may therefore provide a more comprehensive approach when identifying obesogenic trends and chronic disease risk because they focus on the diet as a whole and highlight these relationships and their resulting health outcomes (Jacques and Tucker, 2001, Fung *et al.*, 2001, Kerver *et al.*, 2003, Hu, 2002).

There are three main statistical methods of assessing dietary patterns commonly used in the literature. They include dietary indices, cluster analysis and factor analysis (Hu, 2002). Dietary indices assess overall diet quality using pre-determined criteria to assess diets, whereas cluster and factor analysis used the actual data to derive dietary patterns from. Cluster analysis aggregates individuals into groups based on commonalities between their eating patterns (Hu, 2002), while factor analysis measures the common variance between food items or food groups to identify combinations of foods that are regularly consumed together (Hu, 2002, Smith *et al.*, 2011). There are two main types of factor analysis: exploratory and confirmatory. Exploratory factor analysis investigates the underlying relationship between the constructs influencing a data set, whereas confirmatory factor analysis tests whether the constructs are related in the predicted way (DeCoster, 1998). The generic term 'factor analysis' encompasses both principal components analysis (PCA) and common factor analysis (Hu, 2002). Principal components analysis is considered to be a type of exploratory factor analysis, however it is commonly reported in the literature as being technically different (Hu, 2002, Field, 2009). Both are variable reduction techniques however factor analysis estimates factors from a derived mathematical model, whereas PCA identifies relationships between the linear components derived from the data set (Field, 2009). In pattern analysis, PCA is commonly referred to as 'factor analysis' and is the primary method used as it is psychometrically sound and is less complex than other factor analysis techniques (Field, 2009).

Literature has shown dietary patterns to be valuable in assessing diet-disease relationships. For this literature review, the most relevant studies using dietary pattern analysis and those that have been conducted recently involving women have been reviewed. Several examples of these studies are presented in table 2.5. Dietary patterns were used in the Dietary Approach to Stop Hypertension (DASH) study, where a dietary pattern was trialled in an attempt to reduce blood pressure in a population (Sacks *et al.*, 1999). The DASH diet significantly lowered participant's blood pressure after following the dietary pattern for 8 weeks, signifying the importance of dietary pattern changes rather than specific nutrients (Sacks *et al.*, 1999). The DASH diet success highlights the potential for this method to be expanded to other areas of health, such as obesity, CVD, type 2 diabetes and the resulting metabolic syndrome.

The western dietary pattern has been identified in literature as being a significant contributor to the increasing body fatness of the population. This pattern is characterised by a high intake of refined grains, red and processed meats, frequent consumption of fast-food, SSB, sweets and desserts which have been associated with a high BMI and an increased risk of chronic disease (Schulze, 2006, Nikpartow *et al.*, 2012, Murtaugh *et al.*, 2007, Murakami *et al.*, 2013, Liu *et al.*, 2003, Liebman *et al.*, 2006). Literature shows the dietary components most strongly associated with weight gain were increased consumption of potato chips, potatoes (french fries, boiled, baked or mashed), SSB, red and processed meats, refined grains, sweets, desserts and alcohol (table 2.5). Strong positive correlations have also been found between weight gain and starches, refined grains and processed foods (Mozaffarian, 2011). This dietary pattern is common in obese individuals where these food items are likely to be in their top 10 favourite foods, with women preferring foods high in sugar and fat (Lahti-Koski *et al.*, 2002). Consuming an empty calorie, energy dense diet (e.g. high in animal and vegetable fats, sweets, desserts, SSB and low in fruit, vegetables and fibre) has been shown by Quatromani *et al* (2002) to be associated with a 40% increased risk of obesity. These foods are energy dense and have a low satiety factor thus they are easy to over consume and contribute to excess energy intake (Mozaffarian, 2011).

Table 2.5 Studies investigating dietary patterns and body fatness.

Author(s) and location	Study design	Purpose	Population	Methods	Findings and conclusions
Suliga, 2015 Poland	Cross-sectional study	To identify the dietary patterns of individuals with a normal BMI and which dietary patterns are associated with the metabolic syndrome.	2479 men and women, 37-66 years; BMI 18.5 – 24.9 kg/m^2.	• Validated FFQ • Principal component factor analysis – food groups • Height, weight, WC, BP • Fasting blood samples (cholesterol, triglycerides, glucose levels)	• Four dietary patterns were identified: 1. Healthy 2. Fat, meat and alcohol 3. Prudent 4. Coca-cola, hard cheese and french fries • A high intake of fish and whole grains ('healthy' pattern) and a low intake of refined grains, sugar and cold processed meat ('prudent' pattern) were associated with a lower risk of the metabolic normal weight obesity syndrome, higher HDL-cholesterol and better blood glucose control.
McNaughton *et al.,* 2008 Australia	Cross-sectional study	To investigate the association between dietary patterns and socioeconomic factors, nutrient intakes and health outcomes in	1086 girls and boys, 12-18 years.	• 108-item self-administered FFQ • Principal component factor analysis - food items • 24 hour food recall • Height, weight, WC, BP, BMI (kg/m^2)	• Three dietary patterns were identified: 1. Fruit, salad, cereals and fish pattern 2. High fat and sugar 3. Vegetables • Dietary patterns were not associated with socioeconomic factors, WC or BMI after adjusting for age, sex, and physical activity.

Author(s) and location	Study design	Purpose	Population	Methods	Findings and conclusions
		adolescents.			• Frequent intake of the 'fruit, salad, cereals and fish' pattern may be associated with diastolic BP in adolescent's ≥ 16 years.
McNaughton *et al.,* 2007 England, Scotland, Wales	Longitudinal study	To investigate the relationship between dietary patterns and the risk factors for chronic disease in adulthood.	569 men and 696 women, assessed at 36, 43, and 53 years.	• Three 5-day food records at 36, 43 and 53 years. • Exploratory factor analysis – food items • Height, weight, WC, BMI (kg/m^2), BP • Non-fasting blood samples (lipids, HbA1c)	• Four dietary patterns identified: 1. Ethnic foods and alcohol 2. Meat, potatoes and sweet foods 3. Fruit, vegetables and dairy 4. Mixed • The 'fruit, vegetable and dairy' pattern was inversely associated with BMI, WC and BP. • A high consumption from the 'meat, potatoes and sweet foods' pattern may increase HbA1c. • Dietary patterns can predict chronic disease risk in adulthood.
Murtaugh *et al.,* 2007 America	Cross-sectional study	To investigate the association between dietary patterns, diet composition, and overweight and	871 Hispanic and 1,599 non-Hispanic women, 25-64 years.	• Interviewed diet history questionnaire • Factor analysis - food groups • Interviewed physical activity, medical and reproductive	• Five dietary patterns were identified: 1. Western 2. Native Hispanic 3. Prudent 4. Mediterranean

Author(s) and location	Study design	Purpose	Population	Methods	Findings and conclusions
		obesity.		questionnaire • Weight, height, BMI (kg/m^2)	5. Dieter The 'western' dietary pattern (high fat dairy foods, refined grains, fast-food, processed meat, red meat, desserts) increases the risk of overweight and obesity. • Following a 'prudent' dietary pattern (low fat dairy, whole grains, legumes, vegetables, and nuts) decreases the risk of obesity by 50% in women.
Newby *et al.,* 2006 Sweden	Longitudinal Study	To determine whether changes in dietary patterns were associated with changes in BMI in women.	33,840 women, 49-55 years.	• 97-item, interviewed FFQ • Principal components factor analysis – food groups • Weight, height, BMI (kg/m^2) • Data collected twice three years apart	• Four dietary patterns were identified: 1. Healthy 2. Western/Swedish 3. Alcohol 4. Sweets • The 'healthy' pattern was inversely associated with BMI. • An increase in the 'healthy' dietary pattern score was associated with a decrease in BMI in obese individuals. • Changes in eating patterns are significantly related to changes in BMI over several years.
Schulze, 2006	Prospective	To determine the	51,670	• 133-item self-administered semi-	• Two dietary patterns were identified:

Author(s) and location	Study design	Purpose	Population	Methods	Findings and conclusions
America	cohort study	relationship between dietary patterns and weight changes in women.	women, 26-46 years.	• quantitative FFQ • Principal component factor analysis – food groups • Demographic and physical activity questionnaire • Height, weight, BMI (kg/m^2) • Data collected at baseline, at year 5 and year 8.	1. Prudent 2. Western • Frequent consumption of fruit, vegetables, whole grains, fish, poultry and salad dressing ('prudent' pattern) is positively associated with a lower BMI • Frequent consumption of red and processed meat, refined grains, sweets and desserts ('western' pattern) may lead to long term weight gain.
Newby, 2004 America	Cross-sectional study	To determine whether dietary patterns are associated to anthropometric changes.	459 healthy men and women, 22-88 years.	• 7 day food record • Exploratory factor analysis – food groups • Demographic and physical activity questionnaire • Height, Weight, WC, BMI (kg/m^2)	• Six dietary patterns were identified: 1. Reduced fat dairy products, fruit and fibre 2. Protein and alcohol 3. Sweets 4. Vegetable fats and vegetables 5. Fatty meats 6. Eggs, bread and soup • Frequent consumption of food items in the 'reduced fat dairy, fruit, and fibre' pattern leads to smaller gains in BMI and WC compared to other dietary patterns.
Newby *et al.,* 2003	Prospective	To investigate the	459 healthy*	• 7 day food record	• Five dietary patterns were found:

Author(s) and location	Study design	Purpose	Population	Methods	Findings and conclusions
America	study	dietary patterns leading to changes in body mass index and waist circumference.	men and women, 30-80 years.	• Cluster analysis – food groups • Height, weight, BMI (kg/m^2) Data collected every 12-24 months for 7 years.	1. Healthy 2. White bread 3. Alcohol 4. Sweets 5. Meat and potatoes • Fruit, vegetables, low fat dairy and whole grains ('healthy' pattern) are associated with smaller gains in BMI and WC compared to a high intake of red and processed meats, fast-food and SSB's ('meat and potatoes' pattern). • Analysing dietary patterns looks at the combination of foods and nutrients and is therefore a useful method to identify causes associated with obesity.
Quatromani *et al.*, 2002	Longitudinal study	To determine the relationship between dietary intake and the development of overweight (BMI ≥25 kg/m^2).	737 women, 30-98 years, BMI 18.5 - 24.9 kg/m^2.	• 145-item semi-quantitative FFQ • Cluster analysis – food groups • Height, weight, BMI (kg/m^2) • Physical activity questionnaire • Data collected every 4 years for	• Five dietary patterns were identified: 1. Heart healthy 2. Light eating 3. Wine and moderate eating 4. High fat 5. Empty calorie

Author(s) and location	Study design	Purpose	Population	Methods	Findings and conclusions
America				12 years.	• Women who consumed a diet reflecting the 'empty calorie' dietary pattern had a poor micronutrient intake and were at a higher risk of being overweight, compared to those who consumed a 'heart healthy' dietary pattern. • Changes in dietary patterns and diet quality may influence weight management in women.
Maskarinec *et al.*, 2000 Hawaii	Cross-sectional study	To investigate the relationship between dietary patterns and body mass index in women	514 women, 35-85 years.	• 209-item self-administered validated FFQ • Principal components factor analysis – food items • A one page questionnaire with 10 soy food items • Height, weight, BMI (kg/m^2)	• Four dietary patterns were identified: 1. Meat 2. Vegetables 3. Bean 4. Cold foods • The 'meat' dietary pattern was positively associated with a higher BMI compared to the 'vegetable', 'bean' and 'cold foods' patterns. • Assessing dietary patterns may be important in determining weight management.

**Healthy = free of chronic disease at recruitment;*
GI = Glycaemic index;
GL = Glycaemic load;
WC = Waist circumference;
BP = Blood pressure;
BMI = Body mass index (kg/m^2);
HDL cholesterol = High density lipoprotein cholesterol;
FFQ = Food frequency questionnaire

In comparison, fruit, vegetables, whole grains, nuts, seeds and yoghurt were associated with less weight gain, which is thought to be due to their nutrient dense, high fibre properties (Mozaffarian, 2011). For this literature review, the most relevant studies addressing different dietary characteristics have been reviewed. Several examples of these that have been recently conducted and included women in the analysis are presented in table 2.6. Individuals who consume a diet composed of the items above generally have a lower BMI and waist circumference with fewer weight related morbidities (Newby *et al.*, 2003, He, 2004, Murtaugh *et al.*, 2007). Women obtaining a favourable nutrient intake profile by following the nutritional guidelines and typically consuming a diet low in saturated fat, high in fruit, vegetables, whole grains and fibre are more likely to have a lower BMI and adequate nutrient intakes compared to those who routinely consume a poor nutrient dense diet (O'Neil, 2010, Quatromani *et al.*, 2002, Wirfalt, 1997).

Specific properties of these foods such as their nutrient density and high fibre content are thought to contribute to their effect on body mass (table 2.6). Fibre slows digestion and increases satiety, thus a larger consumption of these foods would displace other energy-dense foods thereby decreasing overall energy consumption (Mozaffarian, 2011). The fibre content of the foods also decreases the glycaemic index (GI) which is another important factor to consider. Murakami *et al* (2013) found that a large intake of high GI foods (e.g. processed breads and potatoes) and a low intake of lower GI foods (e.g. fruits, whole grain cereals and dairy products) was independently associated with an increased risk of obesity. This has also been shown in a study by Liu *et al* (2003) who also found a positive relationship between increased intake of refined grains and increased body weight in female participants.

Additional dietary patterns of milk and dairy food consumption and snacking behaviours have shown controversial results on body composition in the literature. Interestingly, some studies show no significant weight changes when dairy products or different types of milk are consumed (Mozaffarian, 2011, Gunther *et al.*, 2005). In contrast, a large meta-analysis concluded that dairy intake was associated with an overall healthier eating pattern and lifestyle, both of which are protective of chronic disease (Benatar *et al.*, 2013). Conversely, Lahti-Koski *et al* (2002) observed a positive relationship between whole fat milk consumption and obesity. Additionally, participants who preferred skim milk were more likely to become obese compared to those who did not drink milk at all. Reasons for this finding may be that obese subjects are giving socially acceptable answers or trying to offset their weight gain by choosing low fat items; unaware that they can be laden with sugar, which then may give them license to eat larger portions or more of other foods (Stein, 2004, Nielsen *et al.*, 2002). This

dietary habit may be true for either main meals or snacking throughout the day, as foods such as these are especially prevalent in items which are frequently consumed as snacks.

Snacking between meals can significantly contribute to excess energy intake, leading to weight gain. Basdevant *et al* (1993) found that those who snacked between meals generally consumed more energy from fat and less from protein throughout the day. Snacks tended to be items such as biscuits and pastries during the day, and cheese, beef and pork products as entrees before dinner. Additionally, food cravings were reported by 68% of the snackers and those that craved carbohydrate rich foods ate significantly more snacks per day compared to other snackers. Frequent snacking may lead to an increased dietary variety of undesirable food items. Dietary variety has been found to impact body fatness with a study finding increased food variety from entrees, sweets, snacks, condiments and high carbohydrate foods led to an increased energy intake and consequently an increased BF% (McCrory, 1999). Comparatively, they found that an increase in the variety of vegetable consumption (excluding potatoes) decreased the risk of obesity (McCrory, 1999).

Table 2.6 Studies investigating the relationships between dietary characteristics and body fatness.

Author(s)	Study design	Purpose	Population	Methods	Findings and conclusions
Murakami *et al.,* 2013 United Kingdom	Cross-sectional study	To investigate the relationship between dietary GI and GL and obesity.	678 men and 809 women, 19-65 years.	• 7 day weighed food record • Dietary GI and GL calculated • Height, weight, BMI (kg/m^2), WC, W:H ratio • 7 day physical activity diary	• A high GI and GL diet is independently associated with an increased risk of general and central obesity. • Dietary GL had a positive relationship with general obesity in women. • Breads and potatoes were positive predictors of dietary GI. Fruit, cereals, and dairy products were negative predictors of dietary GI.
Mozaffarian, 2011 America	Prospective cohort study	To investigate the relationship between lifestyle changes and long term weight gain.	98, 320 healthy* women and 22,557 healthy* men, 37-52 years, BMI < 30.0 kg/m^2	• Validated semi-quantitative FFQ • Self-reported weight and height • Medical history and lifestyle questionnaires • Data collected every 4 years for 20 years.	• Dietary and lifestyle factors were independently associated with long term weight gain. • Frequent consumption of potato chips, french fries, SSB, meat and processed meats, refined grains, sweets and desserts were associated with weight gain. • Weight gain was inversely associated with consumption of fruit, vegetables, whole-grains, nuts and yoghurt.
Liu *et al.,* 2003	Prospective cohort study	To investigate the relationship between	74,091 healthy females, 38-63 years.	• 61-item semi-quantitative validated FFQ's	• A higher intake of whole grains was associated with less weight gain and a lower BMI.

Author(s)	Study design	Purpose	Population	Methods	Findings and conclusions
America		refined grains and fibre intake on long term weight gain.		• Height, weight, BMI (kg/m^2) • 12 year study • Dietary data collected every 3 and anthropometric data collected every 2 years over 12 years.	• Women with the highest whole grain intakes had a 49% lower risk of major weight gain. • Weight gain was negatively associated with high fibre, whole grain food consumption and positively associated with refined grain consumption.

** Healthy = free of chronic disease at recruitment;*
BMI = Body mass index (kg/m^2);
WC = Waist circumference;
W:H ratio = Waist to hip ratio

2.2.1 Energy dense diets

Energy density can be defined as the amount of metabolisable energy per gram of food (Crowe *et al.*, 2004). The energy density of a particular food item is determined by its composition; with water and fat being the primary factors (Ledikwe *et al.*, 2005). Fat provides more than twice as much as energy per gram (9 kcal/g; 37.6 kJ/g) than protein and carbohydrate (4 kcal/g; 16.7 kJ/g), thus this coupled with the common low water and fibre content of high fat foods leads to a highly palatable and energy-dense item. Examples include foods such as potato chips, chocolate and doughnuts as they have a relatively low water content compared to fruit and vegetables (Drewnowski, 2004).

The energy density of a diet is closely correlated to its macronutrient distribution. An energy-dense diet is likely to obtain a higher percentage of energy coming from fat (Drewnowski, 2004). Several studies have shown a correlation between a high saturated fat diet (e.g. regular fast-food consumption) and a high BMI (Tremblay, 1989, Miller, 1990). It is thought that individuals consuming a large proportion of saturated fat are more likely to over-consume on any one day and thus may lead to unhealthy weight gain. Crowe *et al* (2004) found a positive relationship between energy density and the fat content of a diet. Passive overconsumption is likely when high fat foods are consumed due to their increased palatability, thus contributing to a positive energy balance. In addition to food, beverages, especially those sugar-sweetened have the potential to significantly increase the amount of energy consumed during the day. Food and fluids may have differential physiological effects on satiety and ad libitum food intake, thus it is important to consider the impact of fluids on energy intake separately (Swinburn, 2004, Mourao *et al.*, 2007).

2.2.2 Sugar sweetened beverages

Specific dietary patterns such as frequent consumption of SSB may be an important factor in increased body fatness (Nicklas, 2001). The term SSB encompasses all sweetened beverages such as soft drinks, fruit juice, cordials, sports drinks and iced teas. In the 2008/09 New Zealand Adult Nutrition Survey, 34.5% of the female population aged 15 years and over consumed fruit juice or drinks three or more times per week, and 34.7% of females consumed one or more soft drink per week (University of Otago and Ministry of Health, 2011).

The frequent consumption of SSB has been associated with excess caloric intake, increased body fatness and a diet lacking in essential nutrients (Nikpartow *et al.*, 2012, Schulze, 2004, DiMeglio, 2000, Johnson *et al.*, 2009, Van Wymelbeke *et al.*, 2004). A vast amount of literature has demonstrated a positive relationship between frequent SSB consumption and excess

energy intake leading to increased adiposity. Despite this, there is still much controversy surrounding the causal relationship and the role SSB's play in the development of overweight or obesity (Trumbo and Rivers, 2014). For this literature review, recent studies that included women and investigated the effects of SSB's on body composition were reviewed. Several examples of similar studies are presented in table 2.7 and merely showcase literature relevant to this thesis.

Table 2.7 Studies investigating sugar-sweetened beverage (SSB) consumption.

Author	Study design	Purpose	Population	Methods	Findings and conclusions
Trumbo & Rivers., 2014 America	Systematic review	To review the strength of evidence for the relationship between SSB intake obesity risk.	59 Observational and 17 intervention studies in children, adolescents and adults	• Literature search using key words related to obesity	• Inconsistent evidence was found for an association between SSB intake and obesity risk when adjusted for energy balance.
Malik *et al., 2013* America	Systematic review and meta-analysis	To summarise the evidence on SSBs and body weight in children and adults.	32 randomised controlled trials (20 children, 12 adults)	• Literature search (PubMed, EMBASE, Cochrane databases) • Prospective cohort studies and randomised controlled trials • Search conducted in March 2013 • Random and fixed effect models used for the meta-analysis	• The systematic review and meta-analysis both provided evidence that SSB consumption promotes weight gain in children and adults.
Nikpartow *et al.,* 2012	Cross-sectional study	To investigate the relationship between SSB intake and BMI	6,814 men and 7,463 women, 18-65 years.	• 24 hour food record • Cluster analysis • Height, weight, BMI (kg/m^2)	• Seven clusters were identified: 1. Soft drink 2. Fruit drink 3. Tea 5. Beer 6. Plain milk 7. Mix of beverages

Author	Study design	Purpose	Population	Methods	Findings and conclusions
Canada					4. Coffee • After adjusting for energy intake, a high consumption of fruit drink was a predictor of overweight and obesity in women. • Those whose primary beverage of choice was fruit juice (as a type of SSB) were 84% more likely to be overweight than those who drank a combination of beverages. • A strong association was found between SSB consumption and overweight and obesity.
Chen, 2009 America	Prospective study	To examine the relationship between beverage consumption and weight changes in adults.	810 men and women, 25 to 79 years	• Telephone interviewed 24 hour recalls • Two recalls (one week day and one weekend day) were collected at baseline, 6 and 18 months. • Height, weight, BMI (kg/m^2) obtained via weekly group meetings. • Socio-demographic questionnaire	• Decreasing caloric intake from beverages was more significantly associated with weight loss compared to a decrease in calories from solid foods. • A positive relationship was seen between the reduction of SSB intake and weight loss at both 6 and 18 months. • Limiting calorie intakes from beverages, especially SSB's aids in weight loss and preventing weight gain

Author	Study design	Purpose	Population	Methods	Findings and conclusions
Liebman *et al.,* 2006 America	Cross-sectional study	To investigate the association between BMI and dietary intake, eating behaviours and lifestyle factors.	883 men and 1030 women, 18-96 years.	• Eating behaviour and general dietary questionnaires – focussing on markers of a healthy diet • Self-reported height and weight • Demographic questionnaire	• A high BMI was associated with frequent diet soft drink consumption. • Individuals consuming diet soft drinks were more likely to eat fast-food, order super-sized meals and beverages, eat while doing other tasks and were less likely to participant in regular physical activity. • Individuals who drank diet beverages were less likely to engage in other key lifestyle changes that help to facilitate a healthy body weight.
DellaValle *et al.,* 2005 America	Intervention study	To determine whether specific properties of beverages consumed with a meal influence dietary intake.	44 healthy women, 18-60 years.	• Six test meals - ad libitum lunch with compulsory consumption of one of five beverages (water, diet cola, regular cola, orange juice, and milk) or no beverage as the control. • Subjects rated their fullness, hunger, thirst, prospective consumption and nausea using 100-mm visual analog scales.	• Caloric beverages increased the energy intake at lunch compared to non-caloric beverages. • Food intake was not decreased to compensate for the increased energy provided from the caloric beverage. • A caloric or non-caloric beverage with lunch increased ratings of fullness compared to that of no beverage consumption. • Caloric beverages add a significant amount of energy to a meal without affecting satiety ratings.

Author	Study design	Purpose	Population	Methods	Findings and conclusions
				• One meal per week for 6 weeks.	
Schulze, 2004 America	Prospective cohort analysis	To investigate the relationship between SSB's, weight gain and the risk of type 2 diabetes.	51603 healthy women, 24-44 years.	• 133 item self-administered semi-quantitative FFQ. • Biennial questionnaire (weight, height, age, smoking, pregnancies). • Data collected every 2 years for 8 years.	• Frequent SSB consumption provides excess calories leading to weight gain and an increased T2DM risk. • Women who increased SSB consumption from 1 to 1 or more drinks per day gained more weight over a 4 year period than those who consumed less. • Women consuming 1 or more SSB per day were nearly twice as likely to develop T2DM.
Almiron-Roig & Drewnowski, 2003 America	Intervention study	To compare the effects of specific beverages on hunger, thirst, satiety and energy intakes at the next meal.	14 men and 18 women, 18-35 years.	• Weight, height • Four beverages: orange juice, 1% milk, cola, carbonated water • Participants consumed a beverage with a standardized breakfast. • Ratings of hunger, thirst, fullness and desire to eat were recorded. • Food consumption at lunch was	• Inconclusive results to determine whether liquid and solid foods have differential effects on satiety. • Orange juice, milk and cola all increased fullness and satiety and reduced hunger. • Orange juice, milk and cola differed from sparkling water but not from each other in their effects on hunger and satiety ratings. • Energy intakes at lunch did not compensate for the beverage consumption at breakfast.

Author	Study design	Purpose	Population	Methods	Findings and conclusions
				measured. • One session per week for 4 weeks	
Raben *et al.,* 2002 Denmark	Long-term intervention study	To investigate the long term effect of sucrose and artificial sweetener supplementation on ad libitum food intake and body weight regulation in overweight individuals.	6 healthy* men and 35 healthy* women, 20-50 years, BMI 25-30 kg/m^2	• Intervention groups: 1. F&D supplemented with sucrose 2. F&D supplemented artificial sweeteners. • 7-day food diaries completed at weeks 1, 5 and 10. • A three-factor eating questionnaire on dietary habits completed prior and post the intervention period. • Weight, height, and body composition (BIA and DXA scans) was measured every two weeks. • 24 hour urine samples collected during the 6^{th} day and night	• Overweight individuals who consumed large amounts of sucrose mainly as SSB had increased weight, BMI, body fat and BP. • Ad libitum energy intake significantly increased in the sucrose group but stayed the same in the artificial sweetener group. • The weight gain in the sucrose group was thought to be due to liquids being less satiating, inability to compensate for liquid calories, and the inability of overweight individuals to regulate their energy intakes efficiently.

Author	Study design	Purpose	Population	Methods	Findings and conclusions
				during weeks 0, 5 and 10. • 10 week trial	
DiMeglio, 2000 America	Cross-over study	To determine the differential effects of liquid and solid carbohydrates on food intake and body weight	7 males and 8 women, mean age 22.8 years ± 2.73, mean BMI 21.9 kg/m^2 ± 2.2.	• Weight (kg) • Liquid (soda) or solid (jellybeans) carbohydrate load consumed. • 24-hr phone dietary recalls: 3x at baseline and 6x during treatment and washout periods. • Hunger ratings measured twice during intervention. • 2x 4 week periods separated by a 4 week washout period.	• Liquid carbohydrate promotes a positive energy balance. • Solid carbohydrates promote a balanced energy intake. • Consuming solid carbohydrates resulted in a decrease in ad libitum food intake, whereas liquid carbohydrate consumption did not. • Body weight and BMI significantly increased over the 4 week liquid carbohydrate groups.
De Castro, 1993 Atlanta	Observational study	To investigate the effect of consumption of food and beverages on	124 male and 199 females, 17-75 years, BMI 17.7 - 38.1 kg/m^2	• 7-day food diary • Rating of hunger and satiety before and after eating, respectively.	• Energy consumption is elastic and independent of any single dietary component. • The consumption of caloric beverages, diet soda, tea or coffee did not significantly change the amount of energy consumed.

Author	Study design	Purpose	Population	Methods	Findings and conclusions
		nutrient intakes throughout the day			• When subtracting the energy of the caloric drink from overall food intake, the energy from food was equivalent to days where the drink was not consumed.
Tordoff & Alleva, 1990 America	Cross-over study	To investigate whether artificial sweeteners aid in long-term weight management and food intake.	21 males and 9 females, mean age 22.9 years ± 0.8 for males and 28.2 ± 2.7 for females.	• Consumption of a 1135 g beverage sweetened with high fructose corn syrup, aspartame or no drink each day for 3 weeks each. • 40-item eating attitudes questionnaire • 51-item restrained eating questionnaire • Dietary record kept for 9 weeks. • Weight, height, BMI (kg/m^2)	• Frequent consumption of large volumes of SSB contributes to weight gain compared to the consumption of artificially sweetened beverages. • The consumption of the SSB significantly increased participant weights by 0.66 kg compared to the aspartame beverage. • Artificially sweetened beverages may aid in weight control by reducing sugar and calorie intake.

SSB = Sugar-Sweetened Beverage;
BMI = Body Mass Index;
FFQ = Food frequency questionnaire;
**Healthy = Free of chronic disease at recruitment;*
T2DM = Type 2 diabetes mellitus;
F&D = Food and Drink;
BP = Blood pressure

Women who increase their SSB consumption from one or less to one or more servings per day has been shown to have a larger weight gain over a four year period (Schulze, 2004). This correlates with findings from Nikpartow *et al* (2012) who found women that primarily choose fruit juice as a beverage are 84% more likely to be overweight, 2.55 times more likely to be obese and 2.05 times more likely to be either overweight or obese compared to those who drank a combination of beverages. Conversely, several studies have reported that unlike soft drinks, fruit juice has been associated with smaller increases in excess adiposity (Schulze, 2004, Mozaffarian, 2011). This is postulated to be due to the lower glycaemic index of fruit juice, the presence of phytochemicals, soluble fibre or the smaller quantities of fruit juice that is frequently consumed leading to lesser caloric intakes (Schulze, 2004).

The exact mechanism for the effects of SSB consumption on body weight is relatively unknown, however several theories have been postulated. Simple sugars such as those found in SSB elicit a hedonic effect by up regulating the expression of hunger signals such as neuropeptide Y and dopamine and decreasing satiety signals such as cholecystokinin and peptide YY, thereby increasing energy intake and leading to overconsumption (Erlanson-Albertsson, 2005). It has been proposed by Schulze *et al* (2004) that those who consume SSB have higher total energy intakes, specifically by 358 kcal/d (1,496.4 kJ/d) on average. In a cross-over study, Tordoff and Alleva (1990) compared the consumption of a soft drink sweetened with high fructose corn syrup (HFCS) to one sweetened with aspartame on body weight. When participants consumed the HFCS beverage they consumed 335 kcal/d (1,400.3 kJ/d) more and significantly increased their weight by 0.66 kg compared to when the aspartame beverage was consumed where energy intake and weight decreased non-significantly by 179 kcal/d (748.2 kJ/d) and 0.17 kg, respectively. Similarly, several studies have also shown energy intakes to be significantly increased in subjects who consume a SSB such as coca-cola, fanta, sprite or fruit juice compared to days when they did not or when a diet beverage was consumed (De Castro, 1993, Raben *et al.*, 2002). This suggests that energy provided as a liquid carbohydrate is not compensated for by solid food intake during the day, thus promoting a positive energy balance (Schulze, 2004, DiMeglio, 2000, Mourao, 2007, De Castro, 1993). This is true, especially for overweight individuals who are less sensitive to dietary manipulation and cannot efficiently adjust their energy intakes accordingly (Raben *et al.*, 2002).

The overconsumption seen with SSB intake may also be explained by its poor satiation effect. Both DellaValle *et al* (2005) and Almiron-Roig & Drewnowski (2003) found that consuming caloric beverages with a meal contributed to the higher overall energy intake without

significantly influencing overall satiety. The result was overconsumption, therefore SSB were deemed to be less satisfying than calories obtained from solid foods. Interestingly, one study found that this may also be true for diet SSB, where energy intake may also be higher due to the increased desire to eat during and following a meal (Liebman *et al.*, 2006). Various theories have been proposed in an attempt to explain the poor satiating properties of SSB. One involves the absence of mastication when they are consumed compared to solid foods. Chewing increases saliva and signals pancreatic and endocrine secretions some of which act to signal satiety such as cholecystokinin, peptide YY and ghrelin. Beverages are also cleared from the stomach faster than solid foods which may also decrease satiety and increase hunger sooner (Chen, 2009).

Additionally, large SSB intake tends to be accompanied by poor dietary and lifestyle habits as they are unlikely to be consumed in isolation to other foods. Large population studies have demonstrated that a high energy intake tends to be paralleled by a high total sugar intake, thus leading to excess caloric consumption, an increased risk of obesity and poor diet quality (Swinburn, 2004, Kvaavik *et al.*, 2005). Sugar- sweetened beverages tend to be consumed in large portion sizes complimented by high fat, sugar and salt laden meals from fast-food restaurants (Brown, 2008). A sedentary lifestyle, smoking and poor diet quality have also been linked to individuals who habitually consumed SSB and thus this group of individuals have a higher prevalence of morbidities such as obesity, type 2 diabetes and CVD (Schulze, 2004). Although SSB's have been shown to lead to increased adiposity by much literature (Malik *et al.*, 2013), the topic remains controversial with more recent literature questioning this relationship (Trumbo and Rivers, 2014, Pereira, 2014).

2.2.3 Fast-food consumption

Fast-food can be defined as food that is easily prepared and readily available from food outlets and restaurants or immediate consumption (Collins English Dictionary, 2015). The frequent consumption of fast-food has been shown to significantly increase the risk of obesity, especially in women (Bowman and Vinyard, 2004, French, 2000, Pereira *et al.*, 2005, Prentice and Jebb, 2003). Fast-food is a popular choice by many as it provides a fast and convenient meal option which is compatible with busy lifestyles (Rosenheck, 2008). Although the variety of fast-food outlets are becoming more diverse with many promoting healthier options, the industry leaders remain those selling items typically energy-dense, nutrient poor, and served in excessive portion sizes (Rosenheck, 2008, Swinburn, 2004). The frequent consumption of these energy-dense items such as burgers, deep fried chips and takeaway curries increases the energy content of the diet contributing to increased adiposity, especially abdominal obesity

which is known to increase the risk of chronic disease (Liebman *et al.*, 2006, Swinburn, 2004, French, 2000). This literature review explored studies that investigated the effect of fast food on body composition. Studies most relevant to this topic, those that included women and used a dietary analysis technique such as a FFQ, eating habits questionnaire or diet history were reviewed. Several examples of recent studies are presented in table 2.8.

Table 2.8 Studies investigating the effects of fast-food consumption.

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
Wilcox *et al.,* 2013 Columbia	Cross-sectional study	To examine the association between fast-food consumption and dietary intake and quality in overweight and obese women.	230 women, 25 - 50 years, BMI >25 kg/m2, waist circumference ≥88 cm.	• 3x telephone interviewed 24 hr recalls within 15 days of each other. • Alternative Healthy Eating Index calculated for diet quality • Weight, height, BMI (kg/m^2) • An ActiGraph accelerometer was worn for 7 consecutive days.	• Women who eat more fast-food have a higher energy intake as a result of consumption of energy dense foods. • Fast-food consumption was significantly associated with a higher energy intake, from meat, grains, SSB, dairy, added sugar, total, saturated and trans fats. • Fast-food consumption was negatively associated with the consumption of fruit, vegetables and whole grains. • The mean nutrient intakes showed a poor diet quality score of 29.9, also increasing the risk of chronic disease.
Smith *et al.,* 2009 Australia	Cross-sectional study	To examine the socio-economic, lifestyle factors and diet quality associated with fast-food consumption.	1277 men and 1585 women, 26-36 years	• 127-item FFQ • Food habits questionnaire • Self-administered demographic and lifestyle questionnaire	• Consuming fast-food was associated with a poor diet quality in both men and women. • Women eating fast-food ≥2x per week were less likely to meet the recommended intakes for fruit, vegetables, dairy, lean meat and legumes. • Consuming fast-food ≥2x per week was associated

Author(s)	Study design	Purpose	Population	Methods	Findings and conclusions
				• Weight, height, WC, BMI (kg/m^2)	with a 25% higher prevalence of obesity in women.
Schroeder *et al.,* 2007 Spain	Prospective study	To identify the relationship between fast-food consumption, BMI, energy intake and diet quality.	1491 men and 1563 women, 25-74 years.	• 165-item FFQ • Mediterranean diet score and healthy eating index calculated for diet quality. • Weight, height and BMI (kg/m^2)	• There is a positive relationship between energy intake, energy density and fast-food consumption. • An inverse relationship was seen with fast-food intake and diet quality. • An increased frequency of fast-food consumption increased BMI and the risk of obesity.
Liebman *et al.,* 2006 America	Cross-sectional study	To determine the association between dietary intake, behaviour and physical activity and a high BMI.	883 men and 1030 women, 18-96 years.	• Socio-demographic questionnaire (age, ethnicity, education, employment status, PA) • Dietary intake and eating habits questionnaire • Self-reported height • Self-reported weight	• BMI was positively associated with fast-food consumption, large portion sizes and diet soft drink consumption.
Pereira *et al.,* 2005	Prospective study	To investigate the reported fast-food	3031 men and women, 18-30	• Qualitative FFQ • Diet history of usual	• Fast-food is independently and positively associated with weight gain and insulin resistance.

Author(s)	Study design	Purpose	Population	Methods	Findings and conclusions
America		consumption habits and changes in body weight and insulin resistance over a 15 year period.	years.	• dietary practices • Structured interview obtaining information on dietary practices, food preparation methods and location of meals. • Standardised demographic, behavioural and PA questionnaires.	• Frequent fast-food consumption was associated with higher intakes of total energy, total fat, saturated fatty acids, SSB, refined grains, meat and low fibre intakes. • Frequent fast-food consumption was associated with lower intakes of fruit, non-starchy vegetables, whole grains and reduced fat dairy products.
French, 2000 America	Prospective study	To examine the relationship between demographics, behavioural and dietary factors and frequency of fast-food consumption.	891 healthy* women, 20-45 years, mean BMI 27.0 kg/m^2	• 60-item validated FFQ • TFEQ • PA questionnaire • Weight, height, BMI (kg/m^2) • Data obtained once per year for 3 years	• Fast-food intake was associated with an increased energy intake, percentage energy from fat and a higher body weight. • Consumption of vegetables per day was inversely associated with fast-food consumption. • An increase of one serving of fast-food per week was associated with a 55 kcal increase per day and a weight gain of 1.68 kg over 3 months.

FFQ = Food frequency questionnaire; WC: Waist circumference ; TFEQ = Three factor eating questionnaire
*PA = Physical activity; *Healthy = Free of chronic disease at recruitment;*

Liebman *et al* (2006) showed a positive association in women between frequent fast-food consumption and the likelihood of increased adiposity. Pereira *et al* (2005) also found an independent relationship between fast-food consumption and weight gain. In addition, a positive relationship between total energy, fat intake and fast-food consumption was shown by French *et al* (2000). They also found that increasing fast-food consumption by one serving per week led to an increase of 55 kcal per day, which correlated to a weight gain of 1.68 kg over three months (French, 2000). Likewise, consuming fast-food two or more times per week has been reported to lead to a 25% higher prevalence of obesity in women (Smith *et al.*, 2009).

The weight gain observed during frequent fast-food consumption is thought to be due to the lower energy requirements of women in conjunction with a low satiety factor (Liebman *et al.*, 2006). The inability for fast-food to satiate coupled by its high energy density properties means that it is easy to overeat (Liebman *et al.*, 2006). Sensory aspects of fat such as its 'mouth feel' make it pleasant and desirable to eat and thus is sought out in foods (Drewnowski, 1995). Many foods which have a high fat content are also high in energy and this coupled with low fibre and low satiety often leads to passive overconsumption, thus contributing to calories in excess of what is physiologically required (Blundell and Macdiarmid, 1997).

Eating in such a pattern means that the recommended daily intake of the food groups outlined by the Ministry of Health (e.g. fruit, vegetables, dairy, lean meat and legumes, breads and cereals) are unlikely to be met leading to a low nutrient dense diet (Smith *et al.*, 2009, Wilcox *et al.*, 2013). Individuals who frequently consume fast-food typically have a diet characterised by high total energy, saturated fat, salt, sugar, and refined grains, and this is thought to be due to these food items displacing healthier food options such as fruit, vegetables, whole grains and low fat dairy products (Schroeder *et al.*, 2007, Wilcox *et al.*, 2013, Pereira *et al.*, 2005, Paeratakul *et al.*, 2003).

2.3 Macronutrient Distribution

The ratio of carbohydrate, protein and fat which make up total energy intake may be a significant factor in excess adiposity. The Ministry of Health currently recommends 45-65%, 15-25%, and 20-35% of energy come from carbohydrate, protein and fat, respectively (National Health Medical Research Council, 2005). Several studies investigated the macronutrient ratio in regards to excess body fat with aligning results. Miller *et al* (1990) found that as the BF% of women increased, the percentage of fat derived from their diet also increased (35%) whereas the carbohydrate content decreased (46%) compared to lean individuals (29% of energy from

fat and 53% of energy from carbohydrate, respectively). In agreement with this Merchant *et al* (2009) found that women with lower BF%'s tended to consume diets higher in carbohydrates, where a diet composed of 47-64% of energy from carbohydrates was associated with a low risk of obesity. Tidwell & Valliant (2011) found that women with a BF% of at least 37.9% consumed on average 45.8% of energy intake as carbohydrates which was lower than those with less body fat. Fat intakes were shown to vary among women with different BF%'s, with those less and greater than 37.9% body fat having a mean intake of 21.6% ± 6.0 and 32.6% ± 6.2 of total energy intake, respectively.

2.3.1 Compliance with recommendations

The majority of NZE women meet the dietary macronutrient distribution range recommendations. On average, 16.4% of energy is obtained from protein, 33.6% of energy is from fat, and 47.1% of energy is from carbohydrates (University of Otago and Ministry of Health, 2011). The largest provider of protein was from the bread group (11%), butter and margarine provided the most energy from fat (9%) and bread was the largest contributor of carbohydrates (17%) (University of Otago and Ministry of Health, 2011). New Zealand European females consumed on average 73 g of protein, 69 g of total fat, and 211 g of carbohydrate per day. The Ministry of Health recommend no more than 15% of total energy come from sugar per day (National Health Medical Research Council, 2005). In the 2008/09 National Nutrition Survey, females consumed on average 101 g of total sugar per day, which equals 22.6% of total energy intake. Of this, 21.3% came from sugar and sweets and 15.2% came from non-alcoholic beverages (University of Otago and Ministry of Health, 2011). In addition, the Ministry of Health recommend no more than 10% of the energy allowance for fat should come from saturated and trans fats (National Health Medical Research Council, 2005). The National New Zealand Nutrition Survey found that on average, 13.1% of females' energy intakes were coming from saturated fats (University of Otago and Ministry of Health, 2011). These discrepancies of sugar and fat intakes with the recommendations imply that although the majority of New Zealand women meet the main macronutrient recommendations for protein, carbohydrate and total fat, the quality of carbohydrate and fat consumed is the issue driven by undesirable food sources.

Various studies have found that compliance to dietary recommendations is very low in obese individuals. De Abreu *et al* (2013) found that less than 10% of obese participants complied with the daily fruit and vegetable recommendations. Gonelevu *et al* (1997) investigated the fruit, vegetable and cereal intakes in New Zealand European women living in Auckland. They found that the obese women ate more broccoli and less carrot, apricots, kumara and boiled rice than

their non-obese counterparts; nevertheless, they concluded that neither group was meeting the '5+ a day' guideline for fruit and vegetable intake set out by the Ministry of Health (2013). Similarly, overweight and obese individuals have been shown to consume less than the recommended intakes of fruit, vegetables and dairy products and this may be due to the regular consumption of SSB, fast-food, sweets and processed foods which make it harder to conform to the dietary guidelines (Mozaffarian, 2011, Wilcox *et al.*, 2013). This is also demonstrated by Schroeder (2007) where an inverse relationship between fast-food consumption and meeting the daily dietary recommendations was seen.

2.4 Diet Quality

Diet quality is a term used to describe the nutrient adequacy of one's diet (Steyn, 2013, Streppel, 2014). It is the extent to which the diet meets all of the individuals daily energy and nutrient requirements (Steyn, 2013). To obtain high diet quality it is important to eat a variety of food items as no one food contains all of the nutrients needed for good health, thus low dietary variety leads to a poor diet quality (Steyn, 2013, Eckhardt, 2008). Poor diet quality has been associated with lower intakes of fibre, carbohydrates, protein and micronutrients and higher amounts of saturated fat and alcohol (Wolongevicz, 2010). When a diet with low variety is consumed, it tends to be based on starchy foods rather than fruit, vegetables and lean animal products (Steyn, 2013).

Individuals who have poor diet quality tend to have a higher risk of obesity, thus obese individuals appear to be at greater risk of suboptimal micronutrient levels such as vitamin A, vitamin D, zinc, calcium and iron (Wolongevicz, 2010, Eckhardt, 2008, García *et al.*, 2009). Consuming a poor quality diet may exacerbate the risk of chronic disease already experienced by obese and overweight individuals due to excessive adiposity (Ruxton, 2011). Several studies have investigated the relationship between diet quality and obesity. For this literature review, studies most relevant to this topic, specifically those investigating diet quality and body composition in women were reviewed. Several examples of these are presented in table 2.9. Wolongevicz *et al* (2010) found women to have a two-fold increased risk of obesity when consuming a poor quality diet. Women with the lowest diet quality consumed diets low in energy, carbohydrate and micronutrients and higher in total fat, saturated fat and alcohol. These women also gained 2.3-3.6 kg over eight years compared to those consuming a higher quality diet (1.4 kg weight gain). In addition, Sundararajan *et al* (2014) also found an inverse relationship between diet quality and BMI which is strongest among women.

Table 2.9 Studies investigating the relationship between diet quality and body composition.

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
Sundararajan *et al.*,2014 Canada	Cross-sectional study	To assess the relationship between diet quality and BMI.	6325 men and 7211 women, 18-65 years	• 24-hour interviewed dietary recall • DQ: Healthy eating index • Weight, height, BMI (kg/m^2)	• DQ was associated with a lower BMI in obese individuals. • The relationship between DQ and BMI was strongly related in women.
Wolongevicz *et al.*,2010 America	Longitudinal study	To determine the association between diet quality and abdominal obesity risk in women.	1265 healthy* women, 28-62 years	• 3-day food record • DQ: Dietary risk index score • Weight, height, BMI (kg/m^2), WC • Fasting blood samples (blood lipids and HbA1c) • BP • Data obtained once every 4 years for 12 years.	• Women with poor diet quality were twice as likely to be overweight or obese. • Women with the lowest DQ had low intakes of fibre, calcium, protein, carbohydrates and higher consumption of energy, alcohol, and total, saturated, polyunsaturated and monounsaturated fats.
Wolongevicz, 2010	Prospective study	To investigate the relationship between diet quality and the development of overweight/obesity.	590 women, 25-71 years, BMI <25 kg/m^2	• 3-day dietary records per week (two weekdays, one weekend day) • DQ: Framingham nutritional risk score • Food habits questionnaire	• Women with lower DQ were more likely to become overweight or obese. • Women with low DQ had lower energy, carbohydrate, fibre and all micronutrient intakes and higher

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
America				• Weight, height, BMI (kg/m^2), WC • Fasting blood samples (lipids and HbA1c) • BP • Data obtained once every 4 years for 16 years.	alcohol, total, saturated and monounsaturated fat intakes. • Weight gain was on average 1.4 kg for those with higher DQ, compared to 2.3-3.6 kg with low diet quality, over 8 years.
McNaughton *et al.*,2009 Australia	Cross-sectional study	To identify the relationship between diet quality and the presence of pre-diabetes, newly diagnosed diabetes and cardiovascular risk factors.	7441 men and women, aged ≥ 25 years old	• 74-item FFQ developed for use in Australian adults • DQ: Dietary guideline index • Weight, height, BMI (kg/m^2), WC, • BP • 75 g oral glucose tolerance test • Fasting blood samples (lipids and HbA1c)	• A higher DQ was associated with lower systolic BP and fasting blood glucose levels and higher insulin sensitivity in women. • A high DQ was inversely associated with the prevalence of pre diabetes among women. • High DQ was characterised by higher wholegrain, fruit, vegetables, lean protein, and reduced fat dairy products.

DQ = Diet quality; *BP = Blood pressure;*
BMI = Body mass index; *WC = Waist circumference*

Poor diet quality may help to explain the consistent finding of low or deficient levels of several micronutrients in obese individuals. The reasons behind these deficient levels is relatively unknown, however several theories have been postulated. Firstly, obese individuals tend to have adequate intakes of energy, thus their intakes of micronutrient rich food may be low due to poor food choices, or they may have increased requirements due to changes in the absorption, excretion or metabolism of various nutrients (Ruxton, 2011). Secondly, the primary principle in weight loss strategies is to restrict energy intake. As micronutrient intakes are already low in these individuals, further restriction of food intake without increasing the consumption of fruit, vegetables and whole grains may further exacerbate the low micronutrient levels (Ruxton, 2011). Thirdly, studies suggest that individuals who follow a low fat diet (which is thought to be healthy) do not necessarily have a nutrient rich diet (Wirfalt, 1997). In one study, two clusters (soft drink and skim milk clusters) were identified both of which had low fat intakes. The micronutrient intakes between each group however differed significantly, with the skim milk cluster having a higher micronutrient intake compared to the soft drink cluster. The soft drink cluster's micronutrient intake was consistent with that seen in individuals who consume a relatively high fat diet (e.g. pastries, meat and white bread clusters) (Wirfalt, 1997).

It is thought that the diet quality of these individuals can be increased by incorporating more fruits, vegetables and whole grains into their diet, while eliminating the consumption of fast-foods and SSB (Bowman and Spence, 2002). When whole grain consumption is increased, micronutrient levels improve with the exception of vitamin B12 and sodium (O'Neil, 2010). The concentrations of both vitamin A and C also increase regardless of whole grains being a poor source of these nutrients. This suggests that individuals who increase their whole grain consumption also increase the quality of other parts of their diet (e.g. fruit and vegetable intake), thus overall consuming a healthier diet (O'Neil, 2010).

2.4.1 Micronutrient status

Excess adiposity disrupts the normal metabolic actions of the body, increasing the risk of hypertension, insulin resistance, diabetes, dyslipidaemia and CVD (Wisse, 2004). The risk depends on the extent to which excess adipose tissue is present, regardless of the individuals BMI, among other factors such as genetic disposition, ethnicity, age and lifestyle (Wisse, 2004). As BF% increases, so too does oxidative stress in the body caused by the secretion of various proteins, hormones and other factors by the excess adipocytes. This oxidative stress leads to tissue damage putting the body in a chronic low-grade systemic inflammatory state due to the

innate immune response, which is thought to contribute to the pathogenesis of insulin resistance (Wisse, 2004, Capurso and Capurso, 2012, Cazettes *et al.*, 2011, Garcia-Bailo, 2011).

Actions of modifiers such as micronutrients on inflammation may assist in reducing the damage of oxidative stress on the body (Garcia-Bailo, 2011). In reverse, inflammation may play a crucial role in determining the micronutrient levels in the blood stream (Chai, 2010). Individuals with excess adiposity have been shown to have low micronutrient levels regardless of their diet quality (Chai, 2010). Although a relatively new area of research, the available evidence routinely shows that overweight and obese individuals who have a higher percentage of fat mass compared to lean mass are more likely to have low levels of various micronutrients compared to that of normal weight women (tables 9, 10, 11, 12). This lower level of micronutrient status is also thought to be independent of dietary intake, even after adjusting for nutrient density of the diet, thus obesity may have a direct influence on micronutrient status in these individuals (Chai, 2010). Various mechanisms have been suggested to explain the low levels of micronutrients in overweight and obese women, and one popular theory is that the cutaneous and dietary fat soluble vitamins become sequestrated by the adipose tissue decreasing its availability for absorption (Martini and Wood, 2006). Another theory states it is due to early stage development of obesity related diseases such as diabetes and CVD, where the body requires more of these nutrients (Ruxton, 2011, Kimmons, 2006).

2.4.2 Vitamin A

Controversy surrounds the correlation between vitamin A levels and BF%. Literature surrounding the relationship between vitamin A status and BF% was explored. Recent studies most relevant to this topic and those that included women between the ages of 16 and 45 years were reviewed. Several examples of these studies are shown in table 2.10. An inverse relationship between vitamin A levels and obesity in women has been found in some studies. Obese premenopausal women to have significantly lower vitamin A levels compared to their normal weight counterparts (table 2.10) (Chai, 2010).

Table 2.10 Studies investigating the relationship between vitamin A status and body composition.

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
Garcia, 2012b Mexico	Cross-sectional study	To determine the association of zinc, vitamin A, C and E concentrations with BMI, central adiposity, body fat and leptin levels.	580 women, 37 ± 7.5 years	• 24 hr recall (1x week day, 1x weekend day) • Weight, height, WC, HC • Body composition (DXA) • Fasting blood samples (glucose, lipids, leptin, zinc, vitamin A, C and E)	• Vitamin A levels were associated with women who had higher leptin concentrations. • High leptin levels were associated with a high body fat percentage. • No significant difference in vitamin A levels between overweight/obese and normal weight individuals.
Chai, 2010a Hawaii	Cross-sectional study	To determine the association between serum soluble micronutrients and BMI.	180 women, 35-46 years. Stratified by BMI: normal (18.5-24.9 kg/m^2); overweight (25-29.9 kg/m^2); obese (>30 kg/m^2)	• Validated FFQ for dietary assessment. • Height, weight, BMI (kg/m^2) • Fasting blood samples (pro-vitamin A (α-carotene, β-carotene, β-cryptoxanthin), non-pro vitamin A (lycopene, lutein/zeaxanthin, α-cryptoxanthin,	• The metabolism of pro-vitamin A may contribute to the differences seen in different body compositions. • Both pro and non-pro vitamin A carotenoid serum levels were significantly lower in the obese BMI subgroup compared to the normal BMI group. • Pro-vitamin A, lutein and total energy intakes were not significantly different between BMI groups.

Author(s)	Study design	Purpose	Population	Methods	Findings and conclusions
				anhydrolutein), tocopherols (α-tocopherol, γ-tocopherol).	
Viroonudomphol *et al.,* 2003 Thailand	Cross-sectional study	To examine the relationship between anthropometric measurements, antioxidant status, and lipid profiles.	Intervention group: 16 males and 56 females, BMI ≥ 25.0 kg/m^2, 16-60 years. Control group: 14 males and 58 females, BMI 18.5-24.9 kg/m^2, 16-60 years.	• Weight, height, BMI (kg/m^2), WC, HC, W:H ratio, MAMC • Fasted blood sample (serum retinol, α-tocopherol, lipid profiles)	• Low concentrations of antioxidant vitamins may increase the risk of coronary artery disease. • Weight, BMI, HC, and MAMC were negatively correlated with serum retinol and serum α-tocopherol in both overweight and obese females. • Lower serum retinol levels were seen in overweight (1.8%) and obese (10.7%) individuals, although not significant.

FFQ = Food frequency questionnaire;
BMI = Body mass index;
WC = Waist circumference;
DXA = Dual-energy x-ray absorptiometry;
HC = Hip circumference;
W:H ratio = Waist to hip ratio;
MAMC = Mid arm muscle circumference;
LDL-c = Low density lipoprotein cholesterol;
HDL -c= High density lipoprotein cholesterol;
TC = Total cholesterol;
TGs = Triglycerides

In contrast Garcia *et al* (2012) found that all overweight, obese and normal weight women had adequate vitamin A levels, however the levels in normal weight women being higher than those with excess BF. Viroonudomphol *et al* (2003) also found no significant differences in serum retinol levels between overweight and normal weight subjects. A mere 1.8% of overweight and 10.7% of obese women were found to have low retinol levels, however this was higher than those with lower BF%'s. Seventy-five percent of the studies in table 10 used serum retinol as the measure of vitamin A status. Serum retinol is the measure of adequate vitamin A levels which in normal individuals is tightly regulated by the liver within a narrow window, and it is only when the vitamin A stores start to become depleted that these levels also drop (Viroonudomphol *et al.*, 2003). It is possible that the difference observed in these studies is due to the participants being at different stages of vitamin A liver store depletion at the time of the study.

The effect of obesity on micronutrient status may be independent of dietary intake. After adjustment for nutrient density, Chai *et al* (2010) found the obese subgroup had on average a 45% lower pro-vitamin A concentration (α-carotene, β-carotene and β-cryptoxanthin), whereas non-pro vitamin A (lycopene, lutein/zeaxanthin α-crytoxanthin and anhydrolutein) was only reduced by 15% in the obese women. Due to no differences seen in the serum carotenoid levels after adjustment for nutrient density, it is unlikely that this difference is due to dietary factors. It was suggested that this is due to the increased chronic inflammation which may lead to a higher requirement of some nutrients in this subgroup of the population. Vitamin A has antioxidant properties, and also works with the immune system to prevent infections and cell damage (Kimmons, 2006). Low carotenoid levels have been associated with increases in oxidative stress, insulin resistance, impaired glucose metabolism, some cancers, and age-related macular degeneration (Kimmons, 2006). A high adiposity leads to a high inflammation level in the body and thus more oxidative stress which may lead to a faster metabolism of pro-vitamin A and increased oxidation of carotenoids causing the smaller decrease in non-pro-vitamin A (Chai, 2010). Larger requirements of total vitamin A would therefore be required to counteract and manage the detrimental effects this has on body tissues (Chai, 2010).

2.4.3 Vitamin D

Vitamin D is one of few micronutrients which have been extensively studied in relation to obesity. An inverse relationship has been shown to exist between increased adiposity and vitamin D levels (Chai, 2010, Blum *et al.*, 2008, Samuel and Borrell, 2013, Lagunova, 2009, Ardawi *et al.*, 2011). The New Zealand 2008/09 Adult Nutrition Survey showed an increase in

the prevalence of vitamin D deficiency as excess adiposity increased in individuals over 15 years of age (figure 2.3). The prevalence of vitamin D deficiency was 4.2 percent in individuals in the normal range and underweight group, and 5.4 percent in those who were obese. This difference was no longer significant however once adjusted for age, sex and ethnicity.

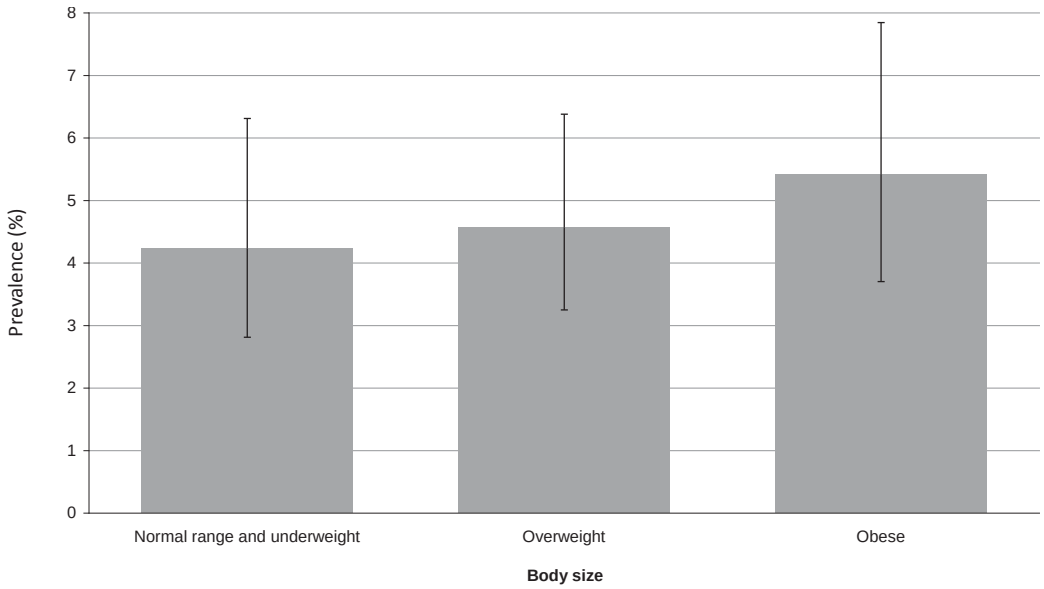


Figure 2.3 The prevalence of vitamin D deficiency by body size in adults over 15 years of age (unadjusted prevalence) (Ministry of Health, 2012) [1].

This positive relationship is also seen in females where low intakes of vitamin D and calcium have been associated with obesity (Moy and Bulgiba, 2011). Blum et al (2008) found that obese women had a significantly lower 25-hydroxyvitamin D level compared to normal weight individuals. This is backed up by Lagunova *et al* (2009) who found a negative association between BMI and both $1,25(OH)_2D_3$ and $25(OH)D_3$ concentrations with 32% (1 in 3) women with a BMI greater or equal to 40 kg/m^2 to have a vitamin D deficiency. Literature surrounding the relationship between vitamin D status and BF% was explored. Studies most relevant to this topic and those that included women between 16 and 45 years old were reviewed. Few studies investigating this topic were relevant to this thesis and those that were are presented in table 2.11. It was concluded that BMI has a negative impact on vitamin D deficiency,

[1] Vitamin D deficiency was defined as a serum 25-OHD level less than 25 nmol/L. Underweight was defined as a body mass index (BMI) of less than 18.5 kg/m2, normal body size was defined as a BMI of 18.5-24.9 kg/m^2, overweight was defined as a BMI of 25.0-29.9 kg/m^2, obesity was defined as a BMI score of greater or equal to 30 kg/m^2.

25(OH)D_3 level and seasonal variance. Further confirmation of this is provided by Samuel & Borrell (2013) who found that overweight and obese individuals were 24% and 55% more likely to have low vitamin D levels compared to their normal weight counterparts, respectively.

Table 2.11 Studies investigating the relationship between vitamin D status and body composition.

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
Ardawi *et al.,* 2011 Saudi Arabia	Epidemiological study	To determine factors influencing vitamin D status in pre and post-menopausal women.	1172 healthy* women, 20-79 years (501 pre-menopausal, 671 post-menopausal), mean BMI 30.6 ± 6.6 kg/m^2	• Standardized socio-demographic questionnaire (lifestyle, smoking habits, PA, tea and coffee consumption, vitamins and medication) • Weight, height, BMI (kg/m^2), W:H ratio • Fasting blood samples (serum 25(OH)D, calcitrol, Ca, PO_4, Mg, creatinine and albumin). • Sun exposure index calculated. • BMD measured using DXA	• Vitamin D deficiency was attributed to the presence of obesity, poor sunlight exposure and poor dietary supplementation. • Obesity was the main risk factor for vitamin D deficiency. • BMI was the best predictor of vitamin D deficiency. • 38.3% of premenopausal women had moderate to severe vitamin D deficiency (serum 25(OH)D < 25 nmol/L). • A negative relationship between vitamin D status and BMI was seen in pre-menopausal women. • Only 16.4% of premenopausal women had vitamin D levels ≥ 75.0 nmol/L.
Tidwell and Valliant, 2011	Cross-sectional study	To determine the relationship between excessive	100 African American women, 18-40 years, Mean	• 24-hour dietary recall • Body composition (DXA)	• Women with lower calcium and vitamin D intakes are likely to have excessive adiposity compared to those with a higher intake.

Author(s)	Study design	Purpose	Population	Methods	Findings and conclusions
America		body fat and levels of vitamin D and calcium	BMI 29.8 kg/m^2		• Women with ≥ 37.9% body fat had calcium and vitamin D intakes of 528.6 mg/d and 3.8 µg/d, respectively. • Women with ≤ 37% body fat had calcium and vitamin D intakes of 911.5 mg/d and 5.0 µg/d, respectively. • An inverse relationship was seen between calcium, vitamin D and BF%.
Lagunova, 2009 Norway	Epidemiological study	To investigate the seasonal variation and the prevalence of vitamin D deficiency in a Norwegian population.	1737 women, < 50 years , mean BMI 31.8 ±6.67 kg/m^2; 805 women, >50 years, mean BMI 31.8±6.28 kg/m^2; 205 men, < 50 years, mean BMI 33±6.91 kg/m2; 184 men, > 50 years, mean BMI 32.3± 5.92 kg/m^2.	• Weight, height, BMI (kg/m^2), body fat mass. • Blood samples (serum 1,25$(OH)_2D_3$ and 25$(OH)D_3$ levels).	• The prevalence of vitamin D deficiency, the 25$(OH)D_3$ level and seasonal variation are all dependent on BMI. • The prevalence of vitamin D deficiency was significantly higher in women with a BMI ≥ 40 kg/m^2.

** Healthy = Participants free of chronic disease at recruitment;*
BMI = Body mass index;
BMD: Bone mineral density;
DXA = Dual-energy x-ray absorptiometry

Several mechanisms are thought to be behind this lower vitamin D level. Firstly, the amount of vitamin D obtained through dietary sources determines the serum concentration in the body and also reflects diet quality. Tidwell & Valliant (2011) have shown that African-American women with a BF% less than or equal to 37.9% had a higher dietary intake of vitamin D and calcium as well as lower intakes of carbohydrates, energy and fat compared to those with higher BF%'s. The dietary intakes in those women with higher adiposity levels revealed that they consumed more SSB, fruit juice and non-fat smoothies. This suggests that a higher diet quality is associated with higher levels of these nutrients (Tidwell and Valliant, 2011).

Secondly, vitamin D is thought to be sequestrated by adipose tissue, thus decreasing the bioavailability of cutaneous and dietary vitamin D sources (Wortsman *et al.*, 2000, Chai, 2010). A study by Blum *et al* (2008) found a positive correlation between vitamin D and storage in adipose tissue. This correlation is thought to be due to the enhanced uptake and reduced availability of vitamin D once deposited in body fat compartments.

Thirdly, it is thought that obese individuals may not be exposed to sunlight as often as their normal weight counterparts and thus may lead to lower serum 25(OH)D levels in this subgroup of women (Chai, 2010). Nevertheless, Wortsman *et al* (2000) found that obese women taking a vitamin D supplement and being exposed to sunlight still had significantly lower vitamin D levels compared to those of normal weight thus suggesting that vitamin D is either metabolised by different metabolic pathway's or sequestrated in individuals with higher BF%'s.

For most people, the main source of vitamin D is skin exposure from sunlight; however dietary intake is also important in maintaining vitamin D status, especially in New Zealanders during the winter months. Small amounts of vitamin D can be found in oily fish (salmon, tuna, sardines), eggs, liver, and fortified foods such as margarines, milk and milk products, and yoghurt (Ministry of Health, 2015c). The fortification of food items such as milk, yoghurt and margarine is voluntary in New Zealand, however in Australia, England, Scotland, Wales and Ireland it is mandatory. Vitamin D deficiency is still highly prevalent in Australia, especially in those who are obese, indicating the sequestration of vitamin D and / or the different dietary patterns between these groups (Australian Government, 2011, Department of Health, 2011, Daly, 2012).

2.4.4 Iron

Poor iron absorption and the resulting iron deficiency are commonly seen in obese individuals, with the literature continuously showing an inverse relationship between iron status and excess adiposity (table 2.12). Literature surrounding the relationship between iron status and

BF% was reviewed. Studies that included pre-menopausal healthy obese women were reviewed. The most relevant studies exploring this topic are presented in table 2.12. Yanoff *et al* (2007) found 26.9% of obese subjects to have iron deficiency based on their serum transferrin receptor, compared to 15.7% in the non-obese group. A negative relationship was seen between serum iron, transferrin saturation, C-reactive protein, BMI and fat mass independent of dietary iron intake. It can therefore be speculated that iron deficiency seen in obese individuals is not related to poor diet quality and more so through other metabolic alterations caused by the increase in adiposity. In correlation with this, Cepeda-Lopez *et al* (2011) concluded that low iron levels in obese individuals is likely to be due to inflammatory mediators influencing iron availability and / or metabolism such as an increase in hepcidin rather than dietary factors. Furthermore, Zimmermann *et al* (2008) investigated the effect of an iron supplement on iron status in those with excess adiposity, and found a negative correlation between iron status and BMI, showing that an iron supplement is insufficient to prevent iron deficiency in these individuals. This study looked at serum ferritin levels after only one iron supplemented breakfast meal. It implies that inflammatory mediators may play an important part in iron status in these individuals; however a longer supplementation period would be beneficial to determine the long term effects.

A mechanism thought to contribute to poor iron status is the inflammatory-mediated sequestration of iron in these individuals (Yanoff *et al.*, 2007). The chronic inflammation causes increased levels of pro-inflammatory cytokines; interleukin-6 and tumor necrosis factor α thus increasing the expression of hepcidin which may reduce iron absorption (García *et al.*, 2009). Iron requirements in overweight individuals may also be increased due to larger blood volume and higher basal iron losses with increased BF%, but this has not been directly measured (Yanoff *et al.*, 2007).

Table 2.12 Studies investigating the relationship between iron status and body composition.

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
Cepeda-Lopez *et al.,* 2011 Mexico	Cross-sectional analysis	To examine the relationships between BMI, dietary iron and dietary factors influencing iron status.	621 premenopausal healthy* women, 18-50 years; 1174 children, 5-12 years.	• Data from the 1999 Mexico Nutrition Survey were analysed. • Validated 24 hour dietary recall interview • Weight, height, BMI (kg/m^2) • Blood and urine samples (HB, serum iron, TIBC).	• The prevalence of iron deficiency was significantly higher in the obese women. • Obese women had significantly lower mean serum iron concentrations (62.6 ± 29.5 µg/dl) compared to the normal-weight group (72.4 ± 34.6 µg/dl). • Dietary iron intakes were not significantly different between BMI groups.
Zimmermann *et al.,* 2008 Thailand	Cross-sectional study	To determine the relationship between iron absorption, status and response to fortification and current BMI.	92 healthy* premenopausal women, 18-50 years, maximum weight of 70 kg	• Intervention group: 4 mg ferrous sulfate consumed in the morning (n = 67); • Control group (n = 27). • Weight • Fasting blood sample (Hb, serum ferritin, zinc, transferrin).	• Excess adiposity predicts poor iron absorption in women independent of dietary intake. • 4% of participants were anaemic, 20% were iron deficient and 22% were overweight. • A negative correlation was found between BMI and iron absorption.
Yanoff *et al.,*	Cross-sectional	To examine the	172 healthy* non-	• 7-day food record	• Serum iron and transferrin saturation was negatively

Author(s)	Study design	Purpose	Population	Methods	Findings and conclusions
2007 America	study	relationship between obesity, serum iron, iron stores and inflammation.	obese (BMI < 30 kg/m^2) and 234 obese (BMI ≥ 30 kg/m^2) men and women, 18 and 70 years.	• Diet history questionnaire • Weight, height, BMI (kg/m^2) • Body composition (DXA) • 10 hour fasted blood sample (serum iron, transferrin, Hb).	correlated with BMI and fat mass. • Mean transferrin receptor, mean ferritin and c-reactive protein were higher in obese subjects. • Adjusted mean daily intake of dietary iron was not different between obese and non-obese subjects. • 26.9% of obese adults had iron deficiency based on serum transferrin receptor compared to 15.7% of non-obese subjects.

**Healthy = Participants free of chronic disease at recruitment;*
BMI = Body mass index;
DXA = Dual-energy x-ray absorptiometry;
Hb = Haemoglobin;
TIBC = Total Iron Binding Capacity

2.4.5 Vitamin E

Several studies have investigated vitamin E status in relation to adiposity levels with conflicting results. The literature surrounding the relationship between vitamin E status and BF% was explored. Studies that included women between 16 and 45 years and those that investigated fasting blood samples were reviewed. Few studies were relevant to this thesis and those that were are presented in table 2.13. Chai *et al* (2010) found significantly higher levels of serum γ-tocopherol in the obese subjects and no significant difference between the groups when comparing serum α-tocopherol levels. Y-tocopherol has anti-inflammatory properties and thus its levels would rise in response to inflammatory signals in the body. The elevated serum γ-tocopherol levels in these obese individuals may therefore reflect systemic inflammation which is present with excess adiposity (Chai, 2010). Garcia *et al* (2009) also found a positive relationship between vitamin E levels and BMI, waist circumference and waist-to-hip ratio. Overweight and obese women had significantly higher vitamin E levels compared to the women of normal body weight. This significance however disappeared after adjusting for total cholesterol and triglycerides, as did the association between vitamin E levels and anthropometrical measurements.

In contrast to the above, several studies have reported low vitamin E levels in obese women. Vitamin E is important for the protection of LDL against oxidation, thus playing a preventative part in CVD development. Low vitamin E levels therefore have been associated with increased levels of oxidative stress, insulin resistance, impaired glucose metabolism and some cancers (Kimmons, 2006). Both Kimmons *et al* (2006) and Mehmetoglu *et al* (2011) reported significantly lower vitamin E levels among obese women compared to those of normal weight. A study by Viroonudomphol *et al* (2003) found 10.7% of overweight/obese women showed significantly lower serum concentrations than those of normal weight. This was in combination with the presence of dyslipidaemia in these subjects where 39.3% had total cholesterol levels above or equal to 6.48 mmol/L and 51.8% had LDL cholesterol levels at or above 3.89 mmol/L.

2.4.6 Zinc

Few studies have investigated the effect of obesity on zinc; however those that have, reported negative correlations. The literature surrounding the relationship between zinc status and BMI was explored. Studies that included women between 16 and 45 years were reviewed. The studies that were relevant to this thesis are presented in table 2.13. Zinc plays an important function in regulating the metabolism of protein, carbohydrates, lipids and nucleic acids in the body (Ennes Dourado Ferro, 2011). Zinc levels may be lacking in many obese individuals and

this is thought to be linked to insulin resistance, hyperglycaemia and impaired glucose tolerance (Ennes Dourado Ferro, 2011). Ennes Dourado Ferro *et al* (2011) found the mean intake of zinc in obese women was greater than women of normal weight, however there was no significant difference in the zinc status between the two groups. This may be due to the study having only looked at zinc levels in plasma. Around 80% of zinc is found in erythrocytes and since erythrocytes have a half-life of approximately 120 days, this is a more sensitive indicator of zinc status in individuals. Further to this Marreiro *et al* (2006) found that despite the good zinc intakes through dietary sources, obese subjects still presented with low serum levels.

2.4.7 Vitamin C

A positive relationship between Vitamin C levels and BMI has been documented (Kimmons, 2006). The literature surrounding the relationship between vitamin C status and BMI was explored. Studies that included women between 16 and 45 years and those that investigated were reviewed. Few studies were relevant to this thesis however those that were are presented in table 2.13. Both Garcia *et al* (2012) and Johnston *et al* (2007) observed an inverse relationship between vitamin C levels and BMI and waist circumference in women. This relationship is thought to be due to the effect vitamin C has on leptin expression. A low vitamin C level was seen with higher leptin concentrations in all women and was still present after adjusting for BMI (table 2.13).

Table 2.13 Studies investigating vitamin E, zinc, vitamin C and their relationships with body composition.

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
Mehmetoglu *et al.,* 2011 Turkey	Cross-sectional study	To investigate the relationship between plasma vitamin A, E, serum coenzyme Q_{10} levels and insulin resistance in obese and normal weight individuals.	21 male and 77 females, BMI > 30 kg/m^2; 20 male and 58 females, BMI < 25 kg/m^2, 18-65 years.	• FFQ • Weight, height, BMI (kg/m^2). • Fasting blood sample (serum CoQ_{10}, vitamin A and E, TC, triglycerides, HDL-c, LDL-c, blood glucose).	• Vitamin E levels of the obese females were significantly lower compared to the normal weight female subjects. • Adjusted vitamin E levels had a significant negative correlation with BMI, waist circumference and waist-to-hip ratio in the control group. • Adjusted vitamin E levels were negatively correlated with waist circumference and waist-to-hip ratio in the obese group. • Vitamin E was positively correlated with age in obese group.
Garcia, 2012a Mexico	Cross-sectional study	To determine the association of zinc, vitamin A, C and E concentrations with BMI, central adiposity, body fat and leptin levels.	580 women, 37 ± 7.5 years	• Weight, height, WC, HC • 3x 24-hour recalls • Body composition (DXA) • Fasting blood sample (glucose, TC, HDL, LDL, TGs, leptin, Vitamin A, C, E and zinc.	• High leptin concentrations were associated with lower zinc and vitamin C levels when stratifying by BMI and BF%. • Vitamin E concentrations were positively associated with adiposity, BMI, WC and W:H ratio. • Vitamin E concentrations were significantly lower in women with lower weight, however after adjusting for lipid concentrations this was no longer significant. • Overweight and obese women consumed significantly

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
					more energy and total fat but similar micronutrient intakes as normal weight women.
Ennes Dourado Ferro, 2011 Brazil	Case-control study	To determine the relationship between biomarkers of the metabolic syndrome and zinc status in obese women	36 normal weight (BMI 18.5 – 24.9 kg/m^2) and 37 obese (BMI > 30 kg/m^2) healthy* premenopausal women, 20-50 years.	• Height, weight, BMI (kg/m^2) • 3-day food record • Fasting blood samples (plasma and erythrocyte zinc levels, lipids, fasting glucose)	• Erythrocyte zinc concentrations are inversely associated with WC and BMI. • No significant differences were seen between the two groups and their plasma zinc concentrations. • Mean zinc intake in the obese women was 10.8 ± 4.7 mg/d and 7.6 ± 2.9 mg/d in normal weight women.
Johnston *et al.,* 2007 America	Cross-sectional study	To examine the relationship between vitamin C, adiponectin, fasting insulin and weight in healthy adults.	35 men and 83 women, 38.7 ± 1.0 years, BMI 18.7 – 47.9 kg/m^2	• Height, weight, BMI (kg/m^2) • Body composition (BIA) • Fasting blood samples (serum vitamin C)	• An inverse correlation was seen between plasma vitamin C levels and BMI, BF% and WC in both men and women. • This significant inverse relationship remained in women after controlling for body mass.
Marreiro *et al.,* 2006	Prospective double-blind, randomised,	To assess the effect of zinc supplementation	56 obese normal glucose tolerant women, 25-45 years,	• Group 1 received 30 mg zinc aminochelate daily for 4 weeks. Group 2	• Low plasma zinc concentrations were seen in obese individuals. • Dietary intake of zinc was adequate and obtained through

Author	Study design	Purpose	Participants	Methods	Findings and conclusions
Brazil	clinical, placebo-controlled study.	on serum leptin levels in insulin resistance.	BMI 36.2 ± 2.3 kg/m^2	received a placebo. • Body composition (BIA) • Fasting blood samples (zinc status, leptin and insulin levels) pre and post intervention period	mainly meat in the obese individuals. • A non-significant increase in plasma zinc concentrations was seen in supplemented group.
Viroonudomphol *et al.,* 2003 Thailand	Cross-sectional study	To examine the association between anthropometric measurements, antioxidant status and lipid profiles.	Intervention group: 16 males and 56 females, BMI ≥ 25.0 kg/m^2, 16-60 years. Control group: 14 males and 58 females, BMI 18.5-24.9 kg/m^2, 16-60 years.	• Weight, height, BMI (kg/m^2), WC, HC, W:H ratio, MAMC • Fasted blood sample (serum retinol, α-tocopherol, lipid profiles)	• Overweight and obese women had lower α-tocopherol levels compared to the normal weight control group. • 10.7% of overweight and obese females had decreased α-tocopherol levels. • A negative correlation was found between weight, BMI, hip circumference and α-tocopherol in both overweight and obese females.

**Healthy = Participants free of chronic disease at recruitment;*
BMI = Body mass index;
WC = Waist circumference;
HC = Hip circumference;
W:H ratio = Waist to hip ratio;
MAMC = Mid arm muscle circumference;
BIA = Bioelectrical impedance analysis;
TC: Total cholesterol
DXA = Dual-energy x-ray absorptiometry;

2.5 Assessing dietary intake

There are generally considered to be five main techniques used to assess dietary intake (table 2.14). The 24-hour recall involves a trained interviewer asking the participant to describe in detail their intake in the last 24 hours. A food frequency questionnaire requires the participant to report on the frequency that they consume an extensive list of foods in the past number of days, months or year. A food record can be estimated intake or weighed intake by the participant and reports the time, type and the amount of each food eaten each day, usually ranging from one to seven days. Finally, a diet history involves the participant to report on their usual intake over an extended period of time, for example the past month or year. The strengths and weaknesses of each method are shown in table 2.14 (Lee, 2010).

Table 2.14. Strengths and weaknesses of the five main dietary assessment techniques (Lee, 2010)

Dietary assessment technique	Strengths	Weaknesses
24-hour recall	• Fast and easy to administer • Inexpensive • Low respondent burden • Can provide detailed information on types of food consumed • Can be used for groups	• Relies on memory • Misreporting occurs • One recall is not representative of an individual's usual intake
Food frequency questionnaire	• Data represents usual intakes • Small participant burden • Can be self-administered • Inexpensive for large sample sizes • Can identify dietary patterns • Can be used for groups	• Relies on the ability of respondent to describe their diet • May not represent participant portion sizes
Weighed food record	• Does not depend on memory • Can be very accurate and provide detailed intake data • Can provide data on eating habits • Multiple day data can be representative of usual intake	• Requires a high degree of cooperation and compliance • Act of recording may alter diet • Large participant burden • Good literacy skills required • Takes more time to obtain data • Data analysis labour intensive and expensive
Estimated food record	• Does not depend on memory	• Estimated not absolute therefore room for error

Dietary assessment technique	Strengths	Weaknesses
	• Can provide data on eating habits • Multiple day data can be representative of usual intake	• Act of recording may alter diet • Good literacy skills required • Data analysis labour intensive
Diet history	• Assesses usual intake • Can detect seasonal changes • Correlates well with biochemical measures	• Long interview process • Required trained interviewers • High degree of cooperation required

2.5.1 Misreporting of energy intake

It is well documented that under-reporting of energy intake through self-reported dietary assessment is common (Bedard *et al.*, 2004). This is a concern in any dietary assessment, especially when estimating habitual intake as it has the ability to introduce bias (Bedard *et al.*, 2004). Factors which influence under-reporting include weight status, age, gender and lifestyle such as smoking and physical activity as well as psychological factors (Bedard *et al.*, 2004, Hyun, 2007, Johansson *et al.*, 1998, Mendez *et al.*, 2004). Under-reporting could also be explained by under-recording, under eating during the assessment period, measurement error, lack of accuracy recorded by the measurement tools provided and participant motivation and comprehension of how to complete the questionnaire (Bedard *et al.*, 2004, Neuhouser *et al.*, 2008, Kipnis *et al.*, 2003). Furthermore, specific food groups may be more likely to be influenced by misreporting depending on how they are perceived. Foods that are perceived as unhealthy (e.g. those rich in refined carbohydrate, fat and sugar such as cakes, confectionary and biscuits) and snack foods may be more likely to be under-reported compared to those thought of as healthy which may be over reported (e.g. fruit and vegetables) (Johansson *et al.*, 1998, Svendsen and Tonstad, 2006). This is thought to be due to the association of these foods with a poor health image, individuals wanting to fit into the acknowledged ideal eating behaviours, and also wanting to please the researcher (Macdiarmid, 1998, Margetts, 2004). Women who under-report have been found to be more likely to report foods which are higher in carbohydrate and lower in fat compared to those who do not under-report their intakes, and obese women have been shown to under-report total energy intake compared to non-obese individuals, possibly leading to skewed predictors of chronic disease risk (Bedard *et al.*, 2004, Gonelevu *et al.*, 1997).

2.5.2 Recovery markers

Recovery markers are commonly used in the literature to measure the accuracy of self-reported energy and protein intakes from dietary assessment tools. The two main methods used are the doubly labelled water protocol (energy biomarker) and a 24-hour urine collection (protein biomarker). The doubly labelled water protocol is considered the gold standard to measure the energy expenditure of individuals under free-living conditions (Poslusna *et al.*, 2009). It uses the stable isotopes ^{2}H and ^{18}O to measure CO_2 production rate from which energy expenditure can be determined (Hill and Davies, 2001). Using the 24-hour urine collection method, nitrogen values are measured in the urine to determine the 24 hour protein intake of individuals. The nitrogen excretion of individuals can however vary widely and therefore this method needs to be performed several times to validate the protein intake of individuals (Poslusna *et al.*, 2009).

2.5.3 Goldberg cut-off

Another method to identify and assess the impact of reporting bias is the Goldberg equation. This has been routinely used to predict total energy expenditure and identify those weight stable individuals that have under-reported their energy intake. It is based on determining the ratio of reported energy intake (EI) to the basal metabolic rate (BMR) of the individual (EI: BMR). The BMR is determined using the age, weight and sex through the Scholfield equation. Under-reporting is identified by using the minimum energy requirements for survival in sedentary individuals (EI <1.35 x BMR). Over-reporting is based on the energy requirements for extremely physically active individuals (EI > 2.4 x BMR). Although the doubly-labelled water technique is the gold standard for assessing individual energy expenditure, it is impractical to be used in large studies due to the cost of materials and the time and expertise required analysing the data. The Goldberg equation, although estimated, is a fast and more cost-effective alternative which is therefore routinely used in the literature (Bedard *et al.*, 2004).

Obesity is a worldwide health problem which increases the risk of many chronic diseases. Specific dietary patterns and macronutrient distributions have been strongly linked to increased adiposity, as have the consumption of energy-dense foods such as sugar- sweetened beverages and fast-food. Further, individuals who have a poor diet quality tend to have a higher risk of obesity. Investigating the dietary intake and eating patterns of New Zealand women will provide greater understanding of the development of different body fat profiles and how we can tailor our dietary advice according.

Chapter 3 Methods

3.1 EXPLORE Study Design

This study was a sub-study of the wider cross-sectional comparative designed study 'Examining Predictors Linking Obesity Related Elements' (EXPLORE) in young adult women. The EXPLORE study investigates how bodyweight and body fat profiles are related to the risk for chronic disease in premenopausal women as well as to investigate how diet and physical activity patterns may impact these profiles and how they may affect miRNA associated with body fat usage and storage. It aimed to recruit225 post-menarcheal, premenopausal New Zealand European (NZE), Maori and Pacific Island women (defined by at least one parent being of the ethnicity) to make a total of 675 participants. The EXPLORE study aimed to recruit an equal number of women (75 women) in each of the three body composition profile (BCP) groups outlined in table 3.1.

Table 3.1 Body composition profile (BCP) groups (Kruger, 2015).

BCP group	**Body mass index (kg/m^2)**	**Body fat percentage (BF %)**
"Normal fat" group (NN)	Normal (18.5-24.9 kg/m^2)	Normal (≥22%, <30%)
"Hidden fat" group (NH)	Normal (18.5-24.9 kg/m^2)	High (≥30%)
"Apparent fat" group (HH)	High (≥25 kg/m^2)	High (≥30%)

BCP group = Body composition profile group;
NN = Normal BMI, normal BF%;
NH = Normal BMI, high BF%;
HH = High BMI, high BF%

This sub-study involved the New Zealand European (NZE) women only and investigated the dietary data obtained from the New Zealand Women's FFQ (NZWFFQ) that was validated in another sub-study of the EXPLORE trial (add ref). At the screening stage, women were categorised into the three BCP groups as outlined in table 3.1 using bio-electrical impedance (BIA) in a non-rigorous community setting. When women participated in data collection for the study, their body composition assessment was conducted using a strict and rigorous ADP protocol, resulting in further profile groups being identified. In addition to the three main BCP groups outlined in table 3.1, this sub-study therefore also included women who had a high BMI with a normal BF% and a normal BMI with a low BF%. As a result the dietary data from women characterising five different body composition profiles were analysed:

- NN - normal BMI (18.5-24.9 kg/m^2); normal BF% (≥22%, <30%)
- NH - normal BMI (18.5-24.9 kg/m^2), high BF% (≥30%)
- HH - high BMI (≥25 kg/m^2), high BF% (≥30%)
- HN - high BMI (≥25 kg/m^2), high BF% (≥30%)
- NL - normal BMI (18.5-24.9 kg/m^2), low BF% (<22%).

These five body composition profiles were included in the dietary analysis describing dietary intakes and patterns of the NZ European cohort to provide a complete dietary assessment of all profiles.

3.2 Ethical Approval

This study protocol was reviewed and approved by the Massey University Ethics Committee: Southern A, Application 13/13. The participants were provided with information sheets and consent forms which were completed prior to data collection. These documents provided the participant with information about the protocols and procedures of the study as well as outlining the inclusion and exclusion criteria for participating in the study, as well as their duties and obligations as participants in the study.

3.3 Study Population

3.3.1 Participants

The wider EXPLORE study aimed to recruit two hundred and twenty five New Zealand European women (75 per profile group). This will provide 80% power at significance levels of $p < 0.05$ to detect a medium effect *f* size of 0.25. It was calculated that approximately 380 NZE women needed to be screened to recruit the 75 eligible women per profile group (Kruger, 2015). Oversampling was performed to ensure that sufficient participants were recruited.

3.3.2 Recruitment

Participant recruitment was conducted over several months (August 2013 - December 2014) in parallel with data collection. The NZE participants were approached through a variety of routes including media and advertising (e.g. local newspapers, websites and local radio stations) and posters and flyers distributed throughout a variety of venues including community groups and churches, medical centres, community events, schools, organisations, and businesses. Social media (e.g. Facebook), emailing lists (e.g. Massey University staff, students, previous research participant databases) and word of mouth were also used throughout the Auckland region. The women were directed to the study website for further information and to register their

interest of participation. The aim was to recruit a convenience sample of NZE, Maori and Pacific Island women.

Pre-screening process

Participants who registered their interest were provided with an information sheet and completed an online health screening and demographics questionnaire through Survey Monkey (or a paper version depending on internet availability) to determine eligibility. This process took 15-30 minutes and included questions on age, ethnicity, parent ethnicity, current and previous health issues (e.g. breastfeeding, diabetes, and cancer) and the regularity and date of their last menstrual cycle (appendix A). If the inclusion criteria were met, participants were deemed eligible and were invited to participate in the screening phase (phase 1) at Massey University, Albany, Auckland. Participants who met the exclusion criteria were contacted via phone or email and their body composition results sent to them.

Inclusion criteria

- NZE women between 16-45 years old
- Post-menarche (defined as having at least one full year or regular menstrual cycle)
- Premenopausal (defined as having had a continuous menstrual cycle for the last complete year)

Exclusion criteria

- Pregnancy
- Lactation
- Any diagnosed chronic disease/illness
- Those actively losing or gaining weight
- Milk allergy

3.3.3 Study setting

Recruitment took place off-site in various areas of Auckland, such as Albany, Henderson and Mangere. The study took place in the Human Nutrition Research Unit (HNRU) at Massey University, Albany Campus, Auckland.

3.4 Procedures

The study entails two phases: screening (phase 1) and main data collection (phase 2).

3.4.1 Phase 1

Screening process

Screening took place in the HNRU at Massey University Albany Campus, North Shore Auckland or off-site at a community venue convenient and appropriate for the participants. Simple anthropometric data of height, weight and body fat percentage (BF%) measurements needed to be obtained to allow for the body composition screen. Height was measured using a portable stadiometer. Weight and BF% were obtained using bioelectrical impedance analysis (BIA) machine (Biospace, Inbody 230, Cerritos, CA). The BIA was used during screening because it provided a non-invasive accurate way to quickly determine the participants body composition. For this measure participants were not fasted, were fully dressed and the time of day was not standardised. The BIA results were not shown to the participants to ensure a blinded study.

Participant's BMI (calculated using height and weight) and BF% results were used for preliminary categorisation into one of the three BCP groups. Eligible participants were invited back to the HNRU at Massey University via phone or email for further testing in phase 2.

3.4.2 Phase 2

Data collection

Participants recruited in phase 2 visited Massey University Albany campus for approximately 2 hours arriving between 7 am and 9:45 am. For the purpose of this study, participants completed:

- Health questionnaire and consent forms
- Anthropometric measures including height, and hip and waist circumference
- Body composition assessment using air displacement plethysmography (ADP) via the BODPOD (2007A, Life Measurement Inc, Concord, Ca., using software V4.2+ as supplied by the manufacturer).
- A validated food frequency questionnaire (FFQ) to assess dietary intake
- A validated New Zealand habits questionnaire to assess dietary and eating habits

Further details of the wider study methodology are outlined elsewhere (Kruger, 2015).

3.5 Body Composition

A full body composition analysis was conducted via air displacement plethysmography (ADP) (2007A, Life Measurement Inc, Concord, Ca., using software V4.2+ as supplied by the manufacturer) using the thoracic gas volume method (Noreen, 2006, Wingfield *et al.*, 2014). This analysis was performed between 8 am and 9:30 am. Participants were fasted overnight (for at least 12 hours) and had not drunk any fluids prior to the ADP analysis. The participants wore tight fitting clothing and a cap to cover hair and minimise its interference with the results. The ADP analysis was conducted by a qualified ADP operator. The body fat results from ADP were used for final categorisation of participants into one of the five BCP groups (Wingfield *et al.*, 2014, Noreen, 2006).

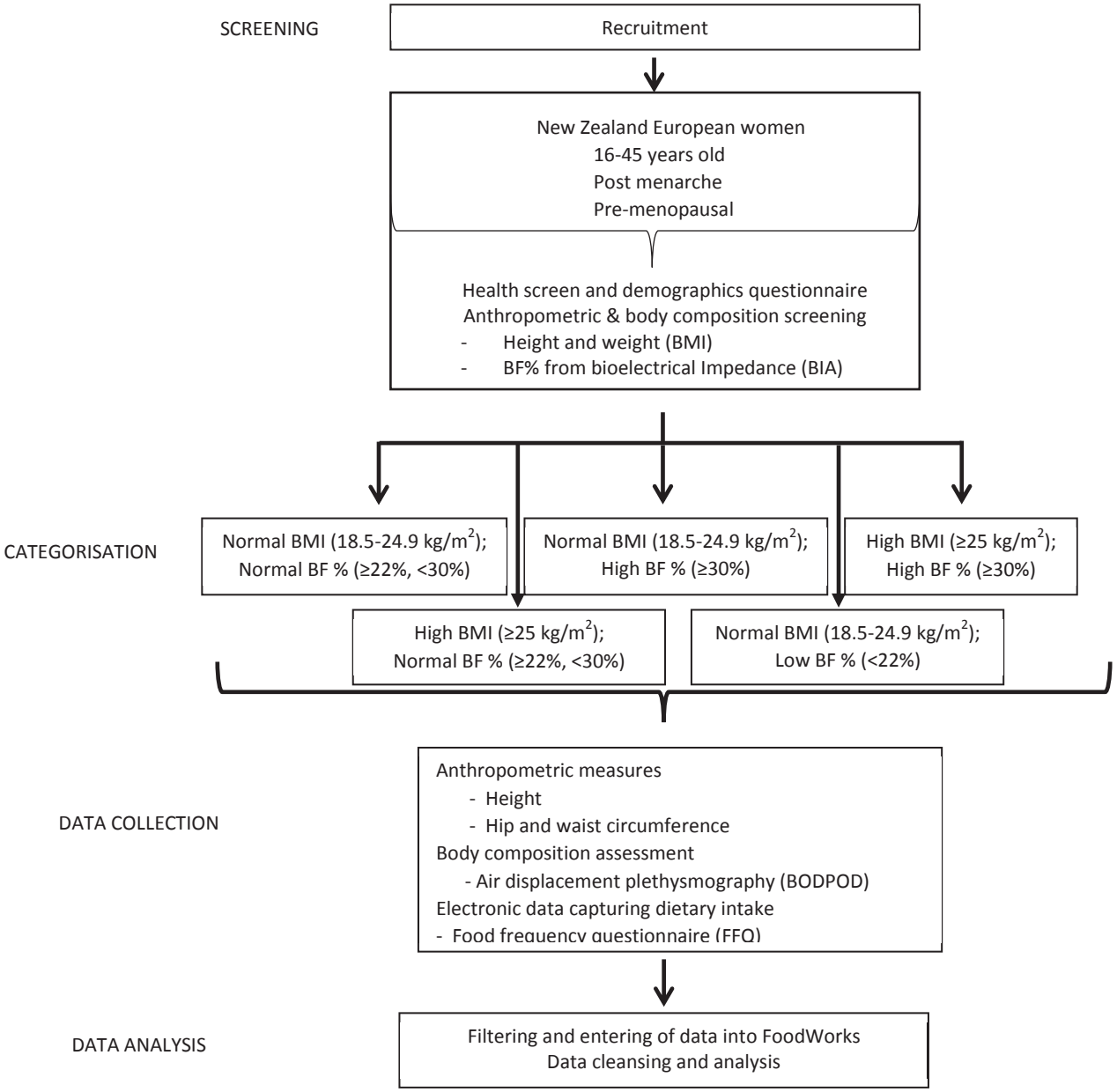


Figure 3.1 Methodological overview of the study.

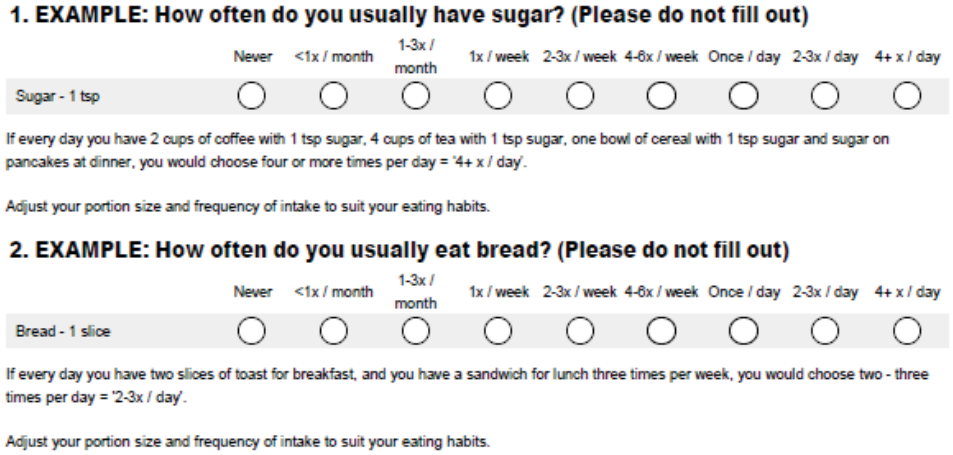
3.6 Dietary Questionnaires

The participants completed a validated 220-item self-administrated semi-quantitative food frequency questionnaire (FFQ) and a validated eating habits questionnaire (EHQ). These were completed in the Human Nutrition Research Unit at Massey University Albany, Auckland campus. The questionnaires were designed and administered using online computer survey software (Survey Monkey). The questionnaires were completed online which minimises interpretation and coding errors, and also ensures a maximum response rate throughout the questionnaire by minimising missing data (Van Selm and Jankowski, 2006). Nevertheless, paper copies of the questionnaires were provided if required which were checked by the supervising research assistant to ensure all questions were answered.

3.6.1 Food frequency questionnaire

The validated, 220-item, self-administrated FFQ (appendix C) was used to assess energy, macronutrients and selected micronutrient intakes of participants over the previous month. It included food lists to encompass frequently consumed foods in each food category (e.g. dairy, breads and cereals, meat, fish and poultry, fats and oils, fruit and vegetables, drinks, dressings and sauces, miscellaneous (cakes, biscuits, spreads) and takeaways), using standard natural portions (e.g. 1 banana) or standard weight and volume measures (e.g. 45 g of oats, 1 pottle of yoghurt). Additional questions included information on usual food preparation methods (e.g. the removal of skin off chicken and cutting excess fat off meat), cooking practises (e.g. the use of oil or butter; frying or baking) and types of food items regularly consumed (e.g. white, wholemeal or wholegrain bread). The FFQ was validated as another sub-study of the EXPLORE study (thesis published; manuscript in preparation). Information on the development and validation of the FFQ is outlined in a Massey University Master's thesis by Houston (Houston, 2014).

Prior to the commencing the questionnaire, participants were provided with verbal instructions following the Standard Operating Procedures (SOP) (appendix B). The research assistant explained the first page of the questionnaire, emphasising the most important points e.g. base your answers on what you eat yourself and not others in your household, and explained two example questions to check participant comprehension (figure 3.2). The participant identification number was checked and entered by the research assistant who was also available for questions throughout completion of the questionnaire.



1. EXAMPLE: How often do you usually have sugar? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sugar - 1 tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯

If every day you have 2 cups of coffee with 1 tsp sugar, 4 cups of tea with 1 tsp sugar, one bowl of cereal with 1 tsp sugar and sugar on pancakes at dinner, you would choose four or more times per day = '4+ x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

2. EXAMPLE: How often do you usually eat bread? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

If every day you have two slices of toast for breakfast, and you have a sandwich for lunch three times per week, you would choose two - three times per day = '2-3x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

Figure 3.2 Food Frequency Questionnaire (FFQ) example questions explained to participant prior to completion.

For each food item, participants reported their average frequency of consumption during the previous month, keeping in mind the standard serving size. This was done by choosing one of nine frequency categories as outlined in table 13. Data was collected from July 2013 to December 2014 therefore all four seasons were captured, thus reducing any discrepancy between seasonal food availability and eating patterns.

3.7 Data Analysis

Food frequency questionnaire data was downloaded from SurveyMonkey into an excel spreadsheet and rearranged into a comprehensive document. All frequencies were translated (table 3.2) and entered into Foodworks 7 (FoodWorks Professional, 2013) dietary analysis database by two MSc students and one research assistant using a template developed specifically for this purpose. Foodworks utilises the New Zealand Food Composition Database (NZ, FOODfiles 2010) developed by New Zealand Plant and Food Research to determine energy, macro- (carbohydrate, protein, total fat, saturated fat) and micronutrient intakes (vitamins A, D and E, C, B6, B12, folate, thiamin, riboflavin, and niacin, dietary fibre), and to assess diet quality. When specific food items were missing from the database, a substitute was entered (e.g. a diet energy drink was entered as diet soft drink). Where specific recipes were required (e.g. protein shake) a new recipe was entered manually e.g. 100g skim milk powder and 250 mL water. The data was checked twice by one of the MSc students to ensure data entry accuracy. Assumptions made during data entry are recorded in Appendix D.

Table 3.2 Frequency translations.

Frequencies	Translation
Never	0m
<1x/month	0.25m
1-3x/month	2m
1x/week	1w
2-3x/week	2.5w
4-6x/week	5w
Once/day	1d
2-3x/day	2.5d
4+x/day	4d

M = Month;
W = Week;
D = Day

Data obtained from the FFQ will be compared to the New Zealand Ministry of Health nutrient reference values (NRVs) for Australia and New Zealand. Specifically, the estimated average requirements (EARs) for women between 19 and 50 years will be used. These values are based on the nutrient requirements estimated to meet the needs of half the healthy population and are used to assess inadequate intake of nutrients within a group setting (National Health Medical Research Council, 2005). The recommended daily intake (RDI) values are set at a higher threshold (2 Standard deviations above the mean) to accommodate for variations in absorption and metabolism of nutrients (National Health Medical Research Council, 2005). They are sufficient to meet the daily needs of 97-98 per cent of healthy individuals, therefore are not appropriate to assess group dietary intakes (National Health Medical Research Council, 2005). Nevertheless, RDI values will still be included to compare nutrient intakes in relation to a higher threshold.

3.8 Food Groupings

All food items in the FFQ were categorised into 56 food groups based on similar nutritional composition and characteristics (table 3.3). Consideration was also given to those foods which are typically consumed together (e.g. crumbed and deep fried) and other individual foods and beverages which are typically or commonly consumed. Individual foods that solely create a food group had to be consumed by at least 10% of the study population. The amount of food groups created were based on the recommendation by Kass & Tinsley (1979) to allocate 5-10 participants per food grouping.

Table 3.3 Food groups

Food Group	Food items included	Justification
Full fat milk	Full fat milk (dark blue top)	High fat content compared to other milks
Low fat milk	Lite milk (light blue top), trim milk (green top)	Often chosen on low fat properties
Sweetened milk products	Breakfast drinks, flavoured milk, evaporated milk, hot chocolate	Sugar added
Yoghurt	Yoghurt (plain, fruity, Greek, unsweetened)	Separate group to other dairy products
High fat cheese	Cheddar, processed cheese, cream cheese, blue vein	High fat content
Low fat cheese	Edam, cottage cheese, brie, camembert, feta	Lower fat content
Apple, banana, orange	Apple, banana, orange	Common fruit available all year round in NZ
Other fruit	Fresh, canned, frozen, dried	Seasonal fruits
Tomatoes	Tomatoes	Good source of lycopene, eaten by >10% of people so can be a group on its own
Dark-yellow vegetables	Carrots, pumpkin	Good source of vitamin C
Green vegetables	Lettuce, spinach, cabbage, broccoli, watercress, green beans, sprouts, courgette	Good source of B vitamins
Other non-starchy vegetables	Capsicum, onion, mushrooms, frozen mixed vegetables, beetroot	Other non-starchy vegetables
Potatoes (excluding chips and crisps)	Potato (boiled, mashed, baked, stuffed, scalloped)	Commonly eaten starchy vegetable, eaten by >10% of people so can be a group on its own
Starchy vegetables	Kumara, yam, parsnip, turnip, swedes (boiled, mashed, baked) Taro (flesh, roots, stalks), green banana, sweet corn kernels	Other starchy vegetables
White breads	White bread, wraps, fruit bread, focaccia, bagel, pita, paraoa bread, rewena bread, doughboys	Refined and processed staple bread products, low fibre
Discretionary breads	Crumpets, scone, savoury muffin, croissant, pancakes/waffles, iced bun	Refined and processed discretionary items, low fibre
Crackers	Cream, cruskit, corn, rice, vitawheat	Different nutrient composition to bread and grains
Whole grain breads	Bread (high fibre, wholemeal, wholegrain)	High fibre
Refined grains	White rice, pasta (penne, spaghetti, vermicelli), noodles (instant, egg, rice), canned spaghetti	White refined carbohydrates
Wholegrains	Brown rice, quinoa, couscous, bulgur wheat	Wholegrains, high fibre
Oats	Porridge, rolled oats, oat bran, oat meal	High fibre, no added sugar
Sweetened cereals	Milo cereal, coco pops, nutrigrain, honey puffs, fruit loops, special K, light and tasty, sultana bran	Added sugar, highly processed
Red meats	Beef (mince dishes, casserole, stew, stir-fry,	Red meats high in protein and saturated

Food Group	Food items included	Justification
	roast, steak) Lamb (stew, casserole, stir-fry) Venison, hogget (roast, chops, steak, casserole, stew, stir-fry), offal (liver, kidney, pate)	fat
White meats	All chicken (breast, leg, wing, casserole, stir-fry) Turkey/quail, pork (roast, chop, steak), mutton bird/duck, veal	White meats high in protein
Processed meats	Sausages, frankfurters, saveloys, cherrioes, bacon, ham, luncheon meats, salami, chorizo, meatloaf, corned beef, patties	All processed, high in saturated fat and salt
Fish and seafood	Canned salmon, canned tuna, canned mackerel Snapper/hoki, gurnard, shark, tuna, salmon Shrimp/prawn, crab, mussels, pipi, whitebait, kina, squid	All fish, high in protein
Egg and egg dishes	Eggs, egg mixed dishes (omelette, quiche, frittata, other baked egg dishes)	All egg protein based
Legumes	Canned/dried (lentils, chickpeas, peas, beans, baked beans), hummus, dahl	All legumes
Soy products	Soybeans, tofu	Soy higher protein than legumes
Peanut butter and peanuts	Peanut butter, peanuts	Different nutrient composition to plain nuts and seeds – sugar and salt added
Nuts and seeds	Nuts (peanut, brazil, walnut, almond, cashew, pistachio) Seeds (pumpkin, sunflower)	All nuts and seeds
Fats	Butter, lard, dripping, ghee	All solid fats
Coconut fats	Coconut milk, cream, oil	Topical
Oil and oil-based dressings	Canola, sunflower, olive, vegetable oils, cooking sprays Salad dressing (French, Italian), Avocado	Avocado classed as a fat rather than a vegetable
Margarine	Margarine – all types	Different to butter and other fat spreads
Creamy dressings	Mayonnaise, creamy dressings, white/cheese sauce, sour cream	Richer and higher fat content than the sauces
Sauces	Tomato, barbeque, chilli, mint, soy, gravy, mustard, chutney, instant soup	Less saturated fat than the creamy dressings
Sweet spreads	Jam, honey, marmalade	High sugar and energy content
Savoury spreads	Vegemite, marmite	Lower energy and sugar
Cakes and biscuits	Cakes, loaves, muffins, sweet pies, pastries, tarts, doughnuts, biscuits (plain, chocolate coated)	All baked sweet discretionary items
Puddings	Ice cream, custard, milk puddings (semolina,	All typically considered and consumed as

Food Group	Food items included	Justification
	instant) Other non-dairy based puddings (pavlova, sticky date pudding), jelly, ice blocks	a dessert item
Sweet snack foods	Chocolate, lollies, muesli bars	Sweet snack foods
Savoury snack foods	Potato chips, corn chips, twisties	Savoury snack foods
Crumbed and deep fried	Crumbed chicken/fish, battered fish, potato fries, chicken nuggets	These are typically eaten together in a meal
Fast-food	Meat pie, sausage roll, savouries, burgers, kebab, Chinese, Indian, Thai, Pizza	Bought high fat fast-foods
Fruit juice	Fruit and vegetable juice	Higher fruit content than fruit drinks
Fruit drink and other beverages	Fruit drink, sparkling grape juice, cordial, iced tea, energy drinks, sports drinks, flavoured water, soft drinks	Higher added sugar
Diet drinks	Diet energy drinks, diet soft drinks, diet cordial	Low calorie drink options
Tea	Black tea, herbal tea	May drink tea not coffee
Coffee	Instant coffee, brewed water-based coffee, espresso	May drink coffee but not tea
Beer	Standard, low alcohol	May drink beer but not wine
Wine (red and white)	White wine, red wine	May drink wine but not beer
Water	Water	Essential in the diet, no energy component, different to other beverages
Other alcoholic beverages	Cider, spirits, sherry, port, ready-to-drink alcoholic sodas (RTD's), kava	All other miscellaneous alcoholic beverages
Sugar added to food and drink	White sugar	Sugar specifically added to foods

3.9 Data Accuracy

3.9.1 Misreporting

The Goldberg equation was performed to highlight participants who misreported their energy intake in relation to their energy requirements in the FFQ. Schofield's equations were used to determine participant basal metabolic rates (BMR) (kilocalories per day) using individual age, gender, weight and height (table 3.4). A physical activity level (PAL) cut off point of 1.55 was used for all participants. This cut off point was determined to be a conservative value which represented seated work and very little strenuous leisure activity (Black, 2000). To derive the cut offs for evaluation of misreporting of energy intakes the SD_{min} and SD_{max} values of -2 and +2 were used for 95% lower and upper confidence intervals, respectively. The revised factors outlined in Black (2000) were also used in this analysis.

Literature reports large bias in energy reporting of overweight and obese individuals (Schoeller *et al.*, 1990). To ensure accuracy participants who were identified as misreporters were excluded in the nutrient analysis but were included in the pattern analysis.

Table 3.4 Scholfield equations.

Age	BMR equation (kcal/d)
10-17	8.4wt + 466ht + 200
18-29	13.6wt + 283ht + 98
30-59	8.1wt + 1.4ht + 844

BMR = Basal metabolic rate
Wt = Weight
Ht = Height
Kcal/d = Kilocalories per day

3.10 Statistical Analysis

The NZWFFQ FoodWorks dietary data were analysed using SPSS 21.0 for windows (SPSS Inc, Chicago IL) computer software system. Data was checked for normality using histogram plots as well as skewness and kurtosis values. Values between -1.96 and 1.96 suggest that the data follow an approximately normal distribution and that no significant difference between the test distribution and a normal distribution is present. Due to the population sample size (n = 231) the Kolmogorov-Smirnov and Shapiro-Wilk tests were not used as they are limited to a sample size of 50 (Royston, 1982). The data was also checked for normality visually, using a superimposed bell curve shape on the histogram, the boxplot, de-trended plot and the Q-Q normality plot. Where improvements to the data were required to improve normality, a natural logarithmic transformation was performed. Descriptive statistics were reported as the mean and standard deviation (SD) for normally distributed data, geometric means and 95% confidence intervals (CI) for the log transformed data, and where normality was not able to be reached, median values and lower and upper quartiles were reported. Other variables were reported as numbers, frequencies and percentages.

3.10.1 Frequency of food item consumption

The 40 most frequently consumed food items were determined for the total population and the three main (NN, NH, HH) profile groups. This included the 26 women identified as under and over reporting their energy intake who subsequently were also included in the food pattern analysis. The HN and NL BCP groups were not included due to small sample sizes (3 and 18 participants, respectively) thus the results would not have been representative of all individuals with these body compositions. The top 40 foods were analysed to identify

differences in food items most commonly consumed between the BCP groups extending out from the main food group items (e.g. bread, milk, oil). Frequencies of consumption for the 220 foods investigated in the FFQ were converted into daily equivalent frequencies and the average frequency of consumption was calculated. The mean daily intake (g per person per day) for each food item was determined by taking the average of the food item weights. Additionally, the number of participants who consumed each of the top 40 foods daily was determined.

3.10.2 Food pattern derivation

Dietary patterns were derived using exploratory factor analysis with factor loadings extracted using principal component analysis, varimax rotation and eigenvalues greater than 1. Orthogonal rotation was used as it is believed that the variables are not highly correlated with each other. The eigenvalue (greater than 1) indicates that the factor is loaded with a greater number of variables or explains more of the variation compared to when the eigenvalue is less than 1. All 231 NZE participants were included in the factor analysis including those who had a body composition outside of the three main BCP groups. The majority of pattern analysis studies include misreporters in the analysis (Devlin *et al.*, 2012). Although evidence is unclear, it is thought that including misreporters in the analysis of dietary patterns does not significantly bias the data outputs (Bailey *et al.*, 2007). Each of the food items were arranged into one of 56 food groups which were entered into the principal component analysis as daily equivalent frequencies.

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett's test of sphericity were used to assess the adequacy of correlation matrices within the data set. If the KMO value is greater than >5, and if the Bartlett's test of sphericity is statistically significant (<0.05) we can be confident in doing a factor analysis (Dziuban, 1974, Frohlich, 2001). To decide how many factors to derive both scree plots and the factors themselves were analysed to identify which factors explained the data best. Food and beverages that loaded highly (≥0.2) were positively associated with the factor and largely contributed to the identified dietary pattern (McNaughton *et al.*, 2011). A negative loading indicated that the item was inversely associated with the factor and thus did not contribute to the dietary pattern. The strength of the association between the food item and the factor is increased as the factor loading increases. Items which cross-loaded with the least loading on a factor were removed from the relevant dietary pattern. Factors were named based food items that loaded highly, the nutritional characteristics and food groupings in each of the identified dietary patterns.

Chronbach's α coefficients were used to assess inter-item reliability. Each factor was assessed individually using the food items that loaded highly because the variance in each of the factors and within all of the food groups is likely to be different (Nunnally, 1994). Food items that indicated that they were skewing the reliability and would increases the scale when taken out were removed from the pattern (for example, factor 4 increased from 0.252 to 0.431 when oil and oil-based dressings, fats and soy milk were removed from the pattern). The factor analysis was re-run without these items to ensure that the removal increased reliability without significantly influencing the dietary patterns (Field, 2009).

Simplified dietary pattern scores were calculated by summing the daily equivalent frequencies for each food item that loaded highly on each of the patterns. The simplified dietary pattern score was developed by Schulze et al (2003) and overcomes the non-comparable limitation of factor analysis by allowing the dietary patterns to relate to other population groups (Schulze *et al.*, 2003). Tertiles for each of the patterns were then determined. Percentage of total number and Chi-square analysis was used to determine associations between the categorical socio-demographic factors and dietary habits across tertiles of each dietary pattern. A one-way ANOVA was performed to compare between the means of nutrient intakes within each dietary pattern, and to analyse the mean age, BMI and BF% within tertiles of each dietary pattern. Post hoc tests of Tukey and Gabriel were used to determine which groups are significantly different from one another. Post hoc tests were used because there is no specific hypothesis that is trying to be proved and it is simply exploring the data to identify trends. Tukey's post-hoc test was used because the sample sizes are the same in tertiles of each dietary pattern.

Chapter 4.0 Results

This chapter presents the findings from a subset of data obtained as part of the women's EXPLORE study; in particular the dietary data of the NZE women. The data presented include participant characteristics, followed by a nutrient analysis of both the total study population and within the BCP groups, the top 40 food items consumed, dietary pattern analysis and finally the diet quality of the NZE women.

4.1 Study Population

A total of 1193 NZ women (including NZE, Maori, and Pacific women) were recruited and 798 women screened for participation in the New Zealand Women's EXPLORE study. Of these, 473 were of NZE decent, and 233 of these women met the inclusion criteria and were invited to complete the study protocol. Oversampling (n = 6) was performed to ensure enough participants were recruited to achieve the objective of recruiting 75 women in each of the main BCP groups (NN, NH, HH). However participant body composition parameters changed following ADP analysis, thus resulting in the following BCP groups: 63 NN, 59 NH, 88 HH, 18 NL, and 3 HN. Two women were excluded from the study as they did not complete the FFQ (1 NN, 1 HH). Twenty four women were identified as mis-reporters (19 under-reporters, 5 over-reporters) based on energy intakes relative to their energy requirements. Of these, 6 NN, 6 NH, and 7 HH women were identified as under reporters, and 1 NN, 1 NH, and 3 HH women were over reporters. These women were excluded in the nutrient analysis but included in the pattern analysis. The final study population used for data analyses therefore was 207 women in the nutrient analysis and 231 women in the pattern analysis (figure 4.1). Allocation of the women into each of the BCP groups is outlined in table 4.1. In the nutrient analysis, 27% of women were in the NN group. In the pattern analysis 30% were in the NN group, 28% in the NH group and 42% in the HH group.

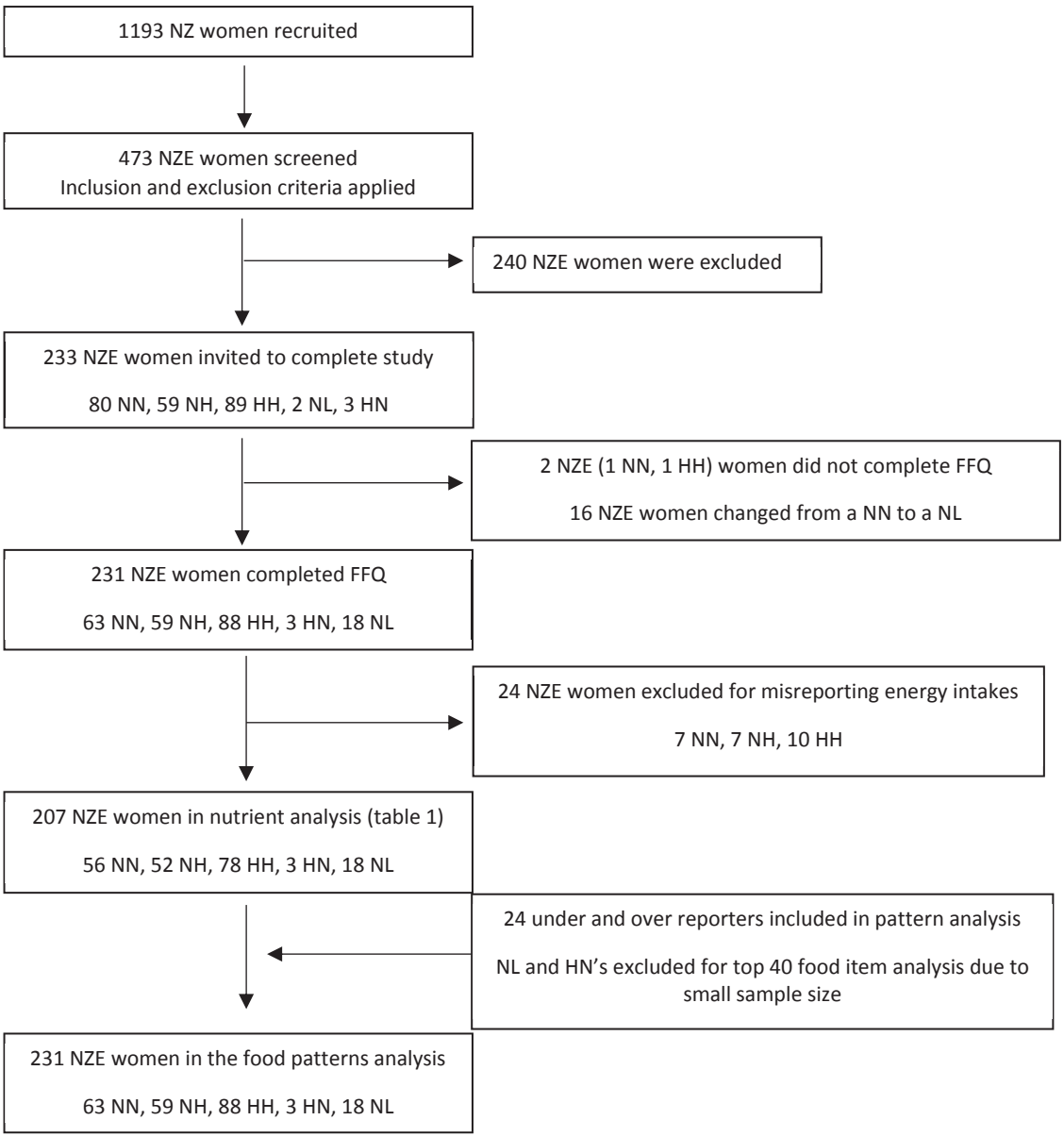


Figure 4.1 Outline of the recruitment process.

Table 4.1 Study population.

BCP groups	Participants included in nutrient analysis (n (%))	Participants included in pattern analysis (n (%))
NN	56 (27)	63 (27)
NH	52 (25)	59 (26)
HH	78 (38)	88 (38)
NL	18 (9)	18 (8)
HN	3 (1)	3 (1)
Total	207	231

NN = Normal BMI (18.5 – 24.99 kg/m^2), normal BF% (22 -29.99 kg/m^2);
NH = Normal BMI, high BF% (≥ 30%); *HH = High BMI (≥ 25 kg/m^2), high BF%;*
NL = Normal BMI, low BF% (< 22%); *HN = High BMI, normal BF%*

4.2 Participant Characteristics

The characteristics of the total study population are outlined in table 4.2. The women had an average age of 31.9 years and a median body mass index (BMI) of 24 kg/m^2. Their average waist to hip ratio, blood pressure and BF% were 0.7, 115/71.7 mmHg, and 32.6%, respectively.

Table 4.2 Characteristics of all New Zealand European study participants (n = 231).

Characteristics	N (%)	NZE women (N = 231)
Age at testing (years)		31.9 (25.2, 39.5) [b]
16-24	54 (23.4)	
25-35	88 (38.1)	
36-45	89 (38.5)	
Height (cm)		167 ± 6.6 [a]
Weight (kg)		70.1 ± 14.2 [a]
Body Mass Index (BMI) (kg/m^2)		24 (21.7, 27.2) [b]
18.5 – 24.99	140 (60.6)	
25.0 – 29.99	60 (26)	
≥ 30.0	31 (13.4)	
Body fat percentage (%)		32.6 ± 8.1 [a]
< 22	18 (7.8)	
22 – 29.9	66 (28.6)	
≥ 30	147 (63.6)	
Waist Circumference (cm)(<80[c])		78.1 ± 11.0 [a]
Hip Circumference (cm)		104.2 ± 10.6 [a]
Waist: Hip ratio (< 0.85[c])		0.7 ± 0.1 [a]
Systolic BP (mmHg) (120[c])		115 ± 9.5 [a]
Diastolic BP (mmHg) (80[c])		71.7 ± 7.4 [a]

[a] *= Mean ± Standard deviation;*
[b] *= Median (25th, 75th percentile);*
[c] *= Standard reference values (World Health Organisation, 2008);*
BMI categories are defined as: Normal: 18.5-24.9 kg/m^2, Overweight: 25.0 – 29.9 kg/m^2, Obese: ≥30.0 kg/m^2;
Body fat percentage categories are defined as: Under: < 22% fat, Normal: <30% fat, High: ≥30% fat

Participant characteristics compared between the BCP groups are outlined in table 4.3. The NN group had the youngest median age (28.2 years (24, 36.4)) and the HH group the oldest (33.8 years (25.5, 40.5)). Body mass index and BF% increased as age increased when comparing the NN, NH and HH BCP groups respectively (BMI 21.4 kg/m^2 (19.9, 23.1), BF% 25.8% (23.5, 28.5); BMI 23.0 kg/m^2 (21.7, 24.4), BF% 33.4% (30.6, 36.4); BMI 28.6 kg/m^2 (24.4, 33.4), BF% 39.1% (33.3, 45.9)).

Table 4.3 Characteristics of participants compared between body composition profile (BCP) groups.

	BCP groups (n = 231)				
Characteristics	NN (n = 63)	NH (n = 59)	HH (n = 88)	NL (n = 18)	HN (n = 3)
Age at testing[a] (years)	28.2 (24, 36.4)	33.1 (25.7, 40.8)	33.8 (25.5, 40.5)	30.7 (23.4, 37.3)	39.0 (26.3, 40.9)
Height [b] (cm)	168.3 ± 6.7	167.6 ± 6.4	166.5 ± 6.9	166.5 ± 6.2	164.2 ± 1.9
Weight [b] (kg)	60.9 ± 7.0*	64.8 ± 5.6*	82.2 ± 15.0*	59.9 ± 7.0*	73.9 ± 1.8
BMI [c] (kg/m^2)	21.4 (19.9, 23.1)*	23.0 (21.7, 24.4)	28.6 (24.4, 33.4)*	21.5 (20.1, 23.0)	27.4 (25.7, 29.3)
BF% [c] (%)	25.8 (23.5, 28.5)*	33.4 (30.6, 36.4)*	39.1 (33.3, 45.9)*	19.7 (18.1, 21.4)*	27.5 (22.9, 33.1)*
WC [b] (cm)	70.1 ± 4.7*	74.5 ± 3.7*	88.0 ± 11.0*	69.0 ± 4.5*	80.3 ± 5.9
HC [b] (cm)	97.5 ± 4.9*	101.4 ± 4.2*	112.4 ± 12.1*	96.7 ± 4.8*	105.6 ± 1.6
W:H ratio [b]	0.7 ± 0.0*	0.7 ± 0.0*	0.8 ± 0.0*	0.7 ± 0.0*	0.8 ± 0.1
Systolic BP [b] (mmHg)	112.2 ± 7.9*	114.3 ± 9.7	117.1 ± 9.9*	115.3 ± 11.0	120.0 ± 8.7
Diastolic BP [b] (mmHg)	68.7 ± 6.3*	71.3 ± 7.8	73.9 ± 7.5*	71.3 ± 6.5	75.0 ± 2.6

[a] = Median (25^{th}, 75^{th} percentiles);
[b] = Mean ± Standard deviation (S);
[c] = Geometric mean (lower, upper quartiles);
**statistically significant(ANOVA between BCP groups);*
BMI = Body mass index;
BF% = Body fat percentage;
WC = Waist circumference;
BP = Blood pressure;
HC = Hip circumference;
W:H ratio = Waist to hip ratio;
NN = Normal BMI (18.5 – 24.9 kg/m^2), normal BF% (22 –29.9%);
NH = Normal BMI, high BF% (≥ 30%);
HH = High BMI (≥ 25.0), high BF%;
NL = Normal BMI, low BF% (< 22%);
HN = High BMI, normal BF%;
n = Number;
BMI categories are defined as: Normal: 18.5-24.9 kg/m^2, Overweight: 25.0 – 29.9 kg/m^2, Obese: ≥30.0 kg/m^2;
Body fat percentage categories are defined as: Under: < 22% fat, Normal: <30% fat, High: ≥30% fat

Participant waist circumference (WC), hip circumference (HC), systolic and diastolic blood pressures increased as BF% and BMI increased between the groups (NN 112.2 mmHg ± 7.9 / 68.7 ± 6.3 mmHg; NH 114.3 mmHg ± 9.7 / 71.3 ± 7.8; HH 117.1 mmHg ± 9.9 / 73.9 ± 7.5 mmHg).

4.3 Dietary Analysis

4.3.1 Total NZE population

The average daily energy intake for the NZE women in this study was 9164 kJ (table 4.4). The women were meeting both the estimated average requirements (EARs) and the recommended daily intakes (RDIs) for all nutrients analysed, apart from Iron where only the EAR was met. Dietary fibre, vitamin E, and potassium intakes also met the adequate intake (AI) levels. Vitamin D intakes were below the AI. Sodium was consumed in excess of the upper limit.

Table 4.4 Mean daily dietary intakes from the NZWFFQ (n = 207) vs. New Zealand National recommendations and percentage of NZE women below the recommendations. (National Health Medical Research Council, 2005).

Nutritional analysis	Mean ± SD, Median (25th, 75th percentile)[a]	EAR[b]	Percent (%) below EAR	NRVs[cdef]	Proportion (%) under and over NRV	Cut off 77% of RDI	Percent (%) below cut off
Energy (kJ)	9164.5 ± 2278.8	na	na	7100-8700[h]	23 U, 50 O[h]	-	-
Protein (g) (% of TE)	96.3 ± 25.7 18.0 ± 3.3[e]	37	0	46[c] 15-25% of TE[e]	0[c] 13 U, 3 O[e]	-	-
Total fat (g) (% of TE)	86.7 ± 28.0 34.8 ± 6.3[e]	na	na	 20-35% of TE[e]	 0 U, 39 O[e]	-	-
Saturated fat (g) (% of TE)	34.8 ± 13.9 13.9 ± 3.5[e]	na	na	 <12% of TE[e]	 66 O	-	-
PUFA (g) (% of TE)	12.8 ± 4.6 5.2 ± 4.0[f]	na	na	 6-10% of TE[f]	 69 U, 2.4 O	-	-
MUFA (g) (% of TE)	29.4 ± 9.5 16.1 ± 3.1[f]	na	na	 10-20% of TE[f]	 29 U, 0.5 O	-	-
Cholesterol (mg)	289.3 ± 142.5	na	na	na	na	-	-
Carbohydrate (g) (% of TE)	233.9 ± 74.6 41.9 ± 7.0[e]	na	na	 45-65% of TE[e]	 64 U, 0 O[e]	-	-
Sugars (g) (% of TE)	124.2 ± 46.6 22.6[f]	na	na	 <15% of TE[f]	 15 U, 84.5 O[f]	-	-
Dietary fibre (g)	30.2 ± 9.6	na	na	25[d]	31[d]	-	-
Thiamin (mg)	1.7 ± 0.8	0.9	7.7	1.1[c]	23[c]	0.8	4
Riboflavin (mg)	2.6 ± 1.0	0.9	0.5	1.1[c]	1[c]	0.8	0
Niacin (mg)	22.4 ± 8.6	11	3	14[c]	9[c]	11	3
Vitamin C (mg)	158.7 ± 83.7	30	0.5	45[c]	1.4[c]	35	0.5
Vitamin D (µg)	4.6 ± 2.3	na	na	5[d]	64[d]	-	-
Vitamin E (mg)	13.5 ± 4.9	na	na	7[d]	6[d]	-	-
Vitamin B6 (mg)	2.5 ± 1.7	1.1	2.4	1.3[c]	4[c]	1.0	1
Vitamin B12 (µg)	4.8 ± 2.5	2.0	5	2.4[c]	9[c]	1.8	2
Total-folate (µg)	439.9 ± 155.6	320	25	400[c]	46.3[c]	308	23
Vitamin A (µg)	1564.7 ± 724.1	500	1	700[c]	4.3[c]	539	1.4
Sodium (mg)	2522.8 ± 861.0	na	na	2300[g]	49[e]	1771	-
Potassium (mg)	3815.5 ± 1080.1	na	na	2800[d]	12.5[d]	-	-
Magnesium (mg)	405.3 ± 112.3	255-265	8.2	310-320[c]	22.2[c]	238	5.3
Calcium (mg)	1233.1 ± 462.5	840	17	1000[c]	38[c]	770	11.5
Phosphorus (mg)	1742.8 ± 468.2	580	0	1000[c]	4.3[c]	770	0
Iron (mg)	12.6 ± 3.5	8	6	18[c]	94[c]	14	67
Zinc (mg)	11.9 ± 3.3	6.5	1.4	8[c]	10[c]	6	1.4
Selenium (µg)	83.4 ± 51.1	50	23	60[c]	33[c]	46	17
Alcohol (g)	4.3 (1.4, 10.2) [a]	na	na	na	na	-	-

[a] = Median (25th, 75th percentile);
[b] NRV-EAR: Estimated Average Requirement;
[c] NRV-RDI: Recommended Dietary Intake;
[d] NRV-AI: Adequate Intake;
[e] NRV-AMDR: Acceptable Macronutrient Distribution Range;
[f] NRV-SDT: Suggested Dietary Targets;
[g] NRV-UL: Upper Limit;
[h] NRV – EER: Estimated Energy Requirement;
NRV = Nutrient Reference Values for New Zealand;
PUFA = Polyunsaturated fat; *O = Over;*
MUFA = Monounsaturated fat; *na =Not Available;*
TE = Total Energy; *U=Under*
SD = Standard Deviation;
All NRVs used were for women 19-30 and 31-50 years old (National Health Medical Research Council, 2005);

Despite the nutrient recommendations being met by the population group, many women consumed less than the NRVs and / or the EARs for many nutrients. Dietary fibre and vitamin D were consumed less than the NRVs by 31% and 64% of women, respectively. Similarly for calcium, iron and selenium, 38%, 94% and 33% of participants consumed less than the NRV for each of these nutrients, respectively. For folate, 25% of participants consumed less than the EAR and 46.5% consumed less than the NRV.

All macronutrients except carbohydrate were within the recommended macronutrient distribution range (AMDR) with 41.9%, 18%, and 34.8% of energy intake coming from carbohydrate, protein and fat, respectively. Thirteen percent of participants consumed below the NRV for protein. Sixty four percent of participants consumed less than the recommended energy intake per day as carbohydrate. Nevertheless, 84.5% of participants consumed over the NRV for sugar per day. A total of 39% of participants consumed over the NRV for fat and 66% consumed over the NRV for saturated fat per day. Polyunsaturated fatty acid intakes were low with 69% of participants consuming less than the NRV per day.

4.3.2 Body composition profile groups

Energy and macronutrients

The energy and macronutrient intakes for each of the body composition profile (BCP) groups are outlined in figure 4.2 and table 4.6. The HH profile group had the largest energy intake per day (9296.2 kJ/d) compared to the HN profile group (7776.8 kJ/d). The NL group consumed the most protein (100.7 g/d), and the NN group consumed the least (93.4 g/d). The NN group consumed the most carbohydrate (242.2 g/d) and the most sugar per day (130.2 g/d), but only consumed 43.2% of energy from carbohydrate. The total and saturated fat content of the diets increased as BF% and BMI increased. The HH group also consumed the most total (89.4 g/d), saturated (36.5 g/d) and monounsaturated fat (30.4 g/d) compared to the other groups. The NL group had the highest intake of polyunsaturated fat (13.5 g/d).

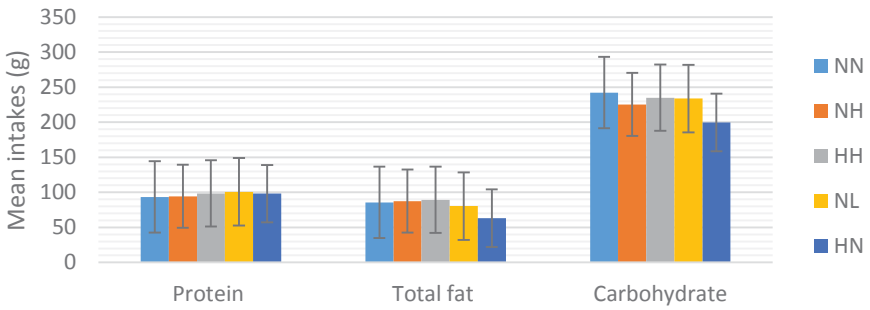


Figure 4.2 Mean (SD) macronutrient intakes compared between the body composition profile groups.

Table 4.5 Nutrient analysis comparison between body composition profile (BCP) groups and with the estimated average nutrient requirements (EAR).

	Recommendations		BCP groups*				
Nutrients	**EAR**	**RDI**	**NN**	**NH**	**HH**	**NL**	**HN**
Energy (kJ)[c]	7100-8700	na	9198.3 ± 2141.0	9057.8 ± 2114.9	9296.2 ± 2505.5	9028.8 ± 2206.2	7776.8 ± 2763.3
Protein (g) [c]	37	46	93.4 ± 25.4	94.3 ± 24.7	98.5 ± 26.5	100.7 ± 27.9	98.2 ± 20.5
Total fat (g) [c]	na	na	85.6 ± 24.3	87.5 ± 26.2	89.4 ± 31.5	80.4 ± 27.4	63.1 ± 24.3
Saturated fat (g) [c]	na	na	34.2 ± 13.0	35.0 ± 13.4	36.5 ± 15.4	31.2 ± 11.5	22.2 ± 9.5
PUFA (g)[a]	na	na	13.0 (9.6, 14.9)	12.2 (10.9, 13.5)	11.9 (10.9, 12.9)	13.5 (10.0, 15.1)	10.5 (5.1, 21.9)
MUFA (g) [c]	na	na	28.8 ± 8.2	29.9 ± 8.8	30.4 ± 10.8	27.0 ± 10.0	22.2 ± 9.1
Cholesterol (mg)[a]	na	na	255.7 (182.7, 323.0)	247.0 (215.0, 283.7)	281.5 (256.3, 309.2)	250.7 (197.0, 344.3)	398.7 (160.3, 991.5)
Carbohydrate (g) [c]	na	na	242.2 ± 72.2	225.4 ± 62.1	235.0 ± 84.0	233.7 ± 71.5	199.6 ± 100.5
Sugars (g) [c]	na	na	130.2 ± 49.9	114.3 ± 33.6	126.2 ± 52.8	128.3 ± 34.6	108.7 ± 69.6
Dietary fibre (g) [c]	na	25 (AI)	31.4 ± 10.6	28.8 ± 8.1	29.5 ± 9.9	32.9 ± 8.8	31.9 ± 15.0
Thiamin (mg)[a]	0.9	1.1	1.4 (1.2, 1.8)	1.6 (1.4, 1.8)	1.5 (1.4, 1.7)	1.65 (1.3, 1.9)	1.8 (1.1, 3.0)
Riboflavin (mg) [c]	0.9	1.1	2.6 ± 1.0	2.7 ± 1.1	2.5 ± 1.1	2.7 ± 0.9	2.9 ± 0.7
Niacin (mg) [c]	11	14	21.4 ± 7.5	21.7 ± 9.1	23.6 ± 9.5	23.0 ± 6.3	20.4 ± 4.2
Vitamin C (mg)[b]	30	45	147.5 (103.1, 190.0)	144.0 (94.3, 160.0)	131.6 (104.9, 192.7)	175.4 (132.7, 210.9)	269.1 (49.7, 273.8)
Vitamin D (µg) [c]	na	5 (AI)	4.5 ± 2.2	4.6 ± 2.9	4.6 ± 2.2	4.6 ± 1.8	4.4 ± 0.6
Vitamin E (mg) [c]	na	7 (AI)	13.4 ± 4.6	13.4 ± 4.8	13.4 ± 5.2	14.4 ± 5.2	13.6 ± 2.7
Vitamin B6 (mg) [c]	1.1	1.3	2.3 ± 0.7	2.5 ± 2.3	2.7 ± 1.8	2.6 ± 0.8	2.6 ± 1.4
Vitamin B12 (µg) [c]	2.0	2.4	4.5 ± 2.1	4.6 ± 2.3	5.1 ± 3.0	5.0 ± 2.3	4.6 ± 1.3
Total-folate (µg) [c]	320	400	462.6 ± 141.7	453.4 ± 155.7	408.9 ± 156.7	467.4 ± 186.4	421.1 ± 136.4
Vitamin A (µg)[c]	500	700	1587.0 ± 767.7	1381.5 ± 496.3	1574.5 ± 756.4	1952.5 ± 903.9	1740.5 ± 507.3
Sodium (mg) [c]	na	2300 (UL)	2457.2 ± 713.3	2468.6 ± 771.6	2661.9 ± 1028.1	2358.2 ± 754	2058.8 ± 375.6
Potassium (mg) [c]	na	2800 (AI)	3823.3 ± 1104.8	3695.0 ± 911.6	3773.1 ± 1146.2	4261.1 ± 1027.5	4187.3 ± 1843.4
Magnesium (mg) [c]	255-265	310-320	412.1 ± 120.9	399.1 ± 95.6	395.2 ± 112.5	444.8 ± 122.8	408.2 ± 166.6
Calcium (mg)[b]	840	1000	1197.7 (979.0, 1494.7)	1257.7 (963.2, 1375.4)	1159.5 (855.4, 1398.7)	1409.4 (132.7, 1620.8)	1386.3 (1142.3, 1768.1)
Phosphorus (mg) [c]	580	1000	1749.5 ± 490.2	1735.0 ± 438.7	1703.9 ± 461.8	1884.7 ± 517.4	1911.0 ± 546.1
Iron (mg)[a]	8	18	11.9 (10.0, 15.5)	11.9 (10.9, 12.9)	12.2 (11.5, 12.9)	13.1 (10.9, 16.1)	12.3 (6.9, 21.9)
Zinc (mg) [c]	6.5	8	11.7 ± 3.1	11.8 ± 3.0	12.0 ± 3.5	12.8 ± 4.1	11.7 ± 3.4
Selenium (µg)[a]	50	60	70.7 (48.1, 92.4)	73.9 (65.1, 83.9)	73.9 (66.1, 82.5)	102.0 (46.1, 125.6)	90.2 (25.3, 321.4)
Alcohol (g)[b]	na	na	4.1 (1.2, 9.1)	5.65 (0.97, 13.0)	3.90 (0.42, 8.38)	4.4 (3.0, 7.1)	8.84 (1.82, 11.2)

[a] = Geometric Mean (lower, upper quartiles);
[b] = Median (lower, upper percentiles);
[c] = Mean ± Standard deviation;
EAR = Estimated average nutrient requirement;
RDI = Recommended daily intake;
AI = Adequate intake
NN = Normal BMI (18.5 – 24.9 kg/m^2), normal BF% (22 – 29.9%);
NH = Normal BMI, high BF% (≥ 30%);
HH = High BMI (≥ 25.0), high BF%;
NL = Normal BMI, low BF% (< 22%);
PUFA = Polyunsaturated fatty acids
MUFA = Monounsaturated fatty acids
** = Values not significant between BCP groups*
UL = Upper limit;
HN = High BMI, normal BF%

Micronutrients

The micronutrient intake for each of the BCP groups is outlined in table 4.6. All of the EAR, RDI, and AI's were met for all of the nutrients analysed except for vitamin D and iron. Vitamin D intakes did not meet the AI in all BCP groups (figure 4.3). Estimated average requirements for iron was met, however the RDI was not (figure 4.3). Excess sodium was also present in all apart from the NL and HN group. Although meeting the nutrient recommendations, the HH profile group had the lowest intakes of riboflavin, vitamin C, folate, magnesium, calcium, and phosphorus compared to the other BCP groups (figure 4.4). They however had the highest intake of niacin, vitamin B6, vitamin B12, and zinc. These findings indicate that the HH group may consume a diet of poor nutrient density with less consumption of fruits, vegetables and dairy products and a higher consumption of meat compared to the other BCP groups.

Sodium intake was consumed in excess in all BCP groups apart from the HN group. The HH BCP group had the largest consumption per day (2661.9 mg/d) (figure 4.7).

The NH group had the lowest intakes of dietary fibre, vitamin E, vitamin A, potassium, and iron. They also had the highest intake of polyunsaturated fat along with the NN group. The NN group also had the highest intake of iron (figure 4.6), and the lowest intakes of thiamin, vitamin B6 and selenium.

The NL group had the highest intakes of thiamine, riboflavin, vitamin D, vitamin E, magnesium, calcium, iron and zinc indicating a nutrient dense diet (figures 4.3, 4.5, 4.6, 4.11). They also had the lowest intakes of cholesterol, and vitamin B12 (figure 4.4). The HN group had the highest intakes of cholesterol, dietary fibre, riboflavin, vitamin C, vitamin A, potassium, phosphorus, iron, and selenium. They had the lowest intake of niacin, vitamin D, sodium and zinc (figures 4.6, 4.8, 4.9, 4.10).

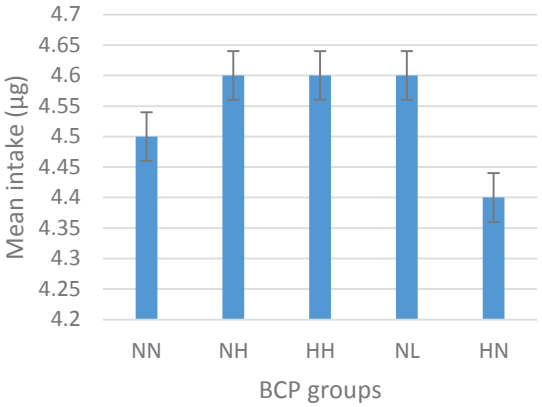


Figure 4.3 Mean (SD) vitamin D intakes of the body composition profile (BCP)

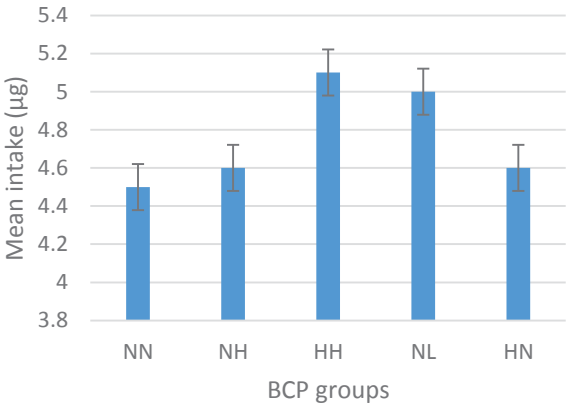


Figure 4.4 Mean (SD) vitamin B12 intakes of the body composition profile (BCP) groups.

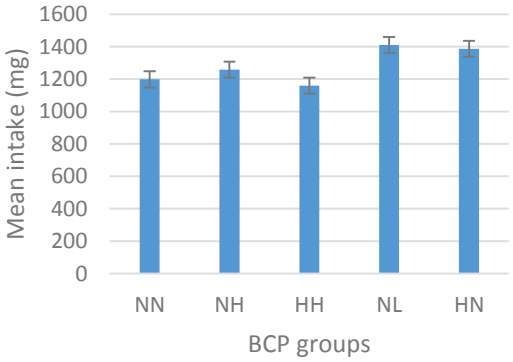


Figure 4.5 Mean (SD) calcium intakes of the body composition profile (BCP) groups.

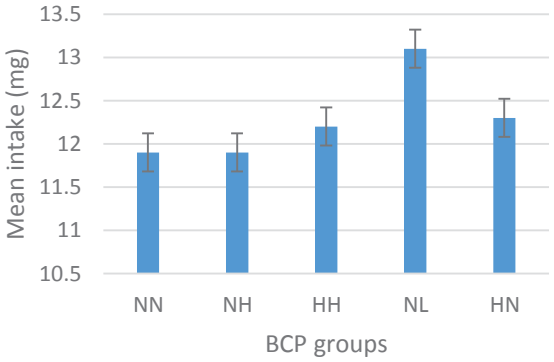


Figure 4.6 Mean (SD) iron intakes of the body composition profile (BCP) groups.

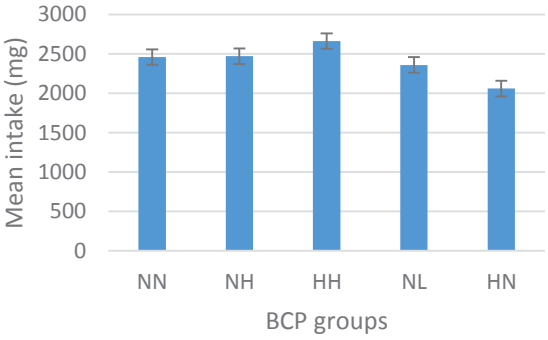


Figure 4.7 Mean (SD) sodium intakes compared between the body composition profile (BCP) groups.

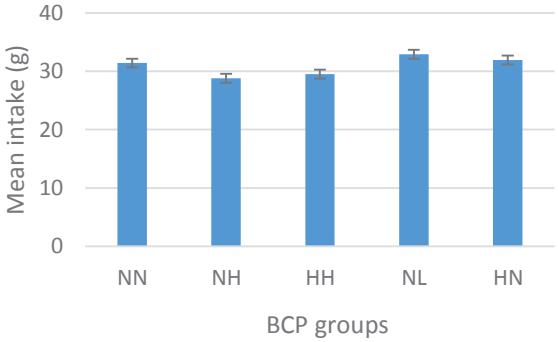


Figure 4.8 Mean (SD) intake of dietary fibre compared between the body composition profile (BCP) groups.

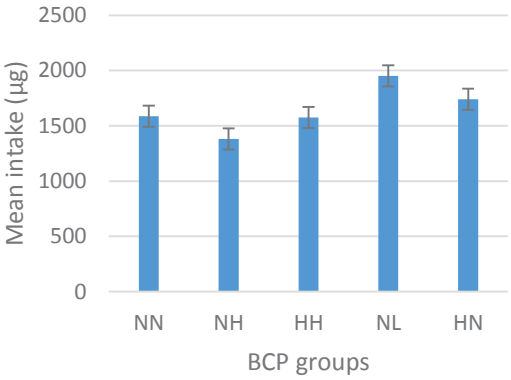


Figure 4.9 Mean (SD) vitamin A intakes of the body composition profile (BCP)

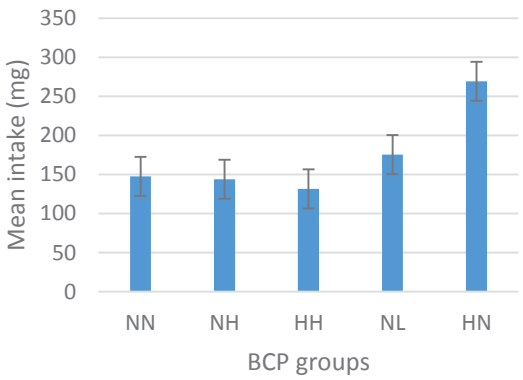


Figure 4.10 Mean (SD) vitamin C intakes of the body composition profile (BCP)

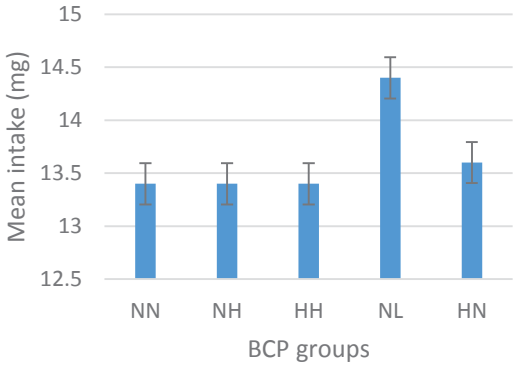


Figure 4.11 Mean (SD) vitamin E intakes of the body composition profile (BCP)

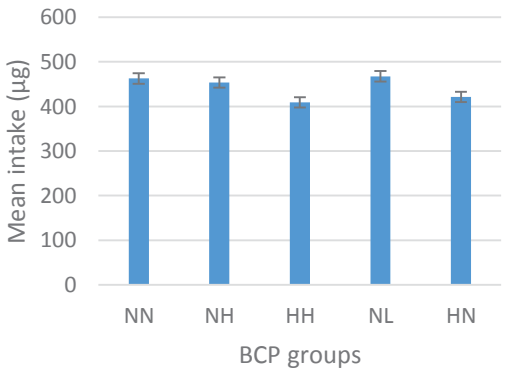


Figure 4.12 Mean (SD) total folate intakes of the body composition profile

4.3.3 Macronutrient distribution

The average macronutrient distribution ranges for each of the BCP groups is outlined in table 4.6.

Table 4.6 Mean macronutrient percentage intakes (%) compared between body composition profile (BCP) groups.

Macronutrient	AMDR	NN	NH	HH	NL	HN
kJ from protein (%)*	15-25	17.3 ± 2.7	17.8 ± 3.2	18.3 ± 3.4	19.1 ± 3.6	22.3 ±3.7
kJ from fat (%)*	20-35	34.4 ± 6.0	35.5 ± 5.6	35.3 ± 6.6	32.5 ± 6.9	30.6 ±7.8
kJ from saturated fat (%)*	<12	13.7 ± 3.5	14.1 ± 3.2	14.3 ± 3.8	12.6 ± 3.2	10.7 ±3.1
kJ from carbohydrate (%)*	45-65	43.2 ± 6.6	40.9 ± 5.6	41.5 ± 7.7	42.8 ± 8.3	40.6 ±9.9

Values reported are mean ± standard deviation;
kJ = Kilojoule;
AMDR = Acceptable macronutrient distribution range;
** = Significantly different (ANOVA between BCP groups);*
NN = Normal BMI (18.5 – 24.9 kg/m^2), normal BF% (22 – 29.9%);
NH = Normal BMI, high BF% (≥ 30%);
HH = High BMI (≥ 25.0), high BF%;
NL = Normal BMI, low BF% (< 22%);
HN = High BMI, normal BF%

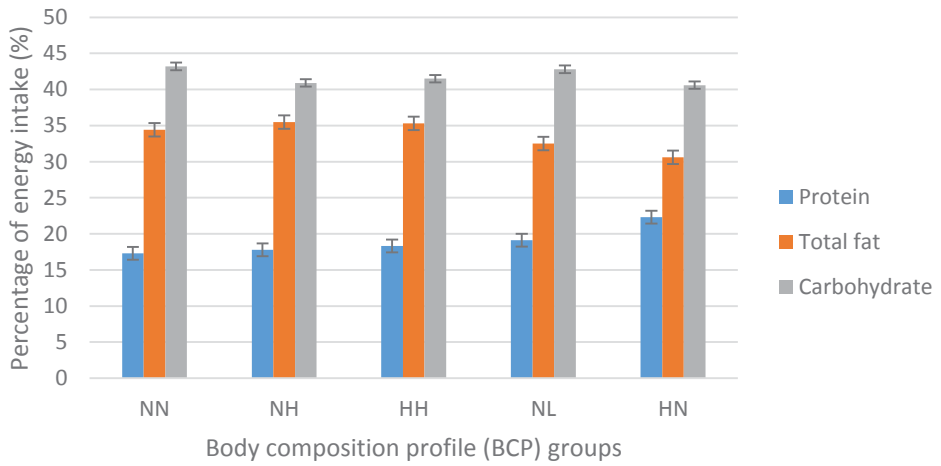


Figure 4.13 Mean (SD) macronutrient intakes as percentage of energy intake compared between the body composition profile (BCP) groups.

None of the BCP groups met all of the acceptable macronutrient daily recommendations (AMDRs). All of the groups reported low carbohydrate intakes below the level of 45% of total energy intake. The NN group reported the highest intake of 43.2% with the NH and HH groups reporting intakes of 40.9% and 41.5%, respectively. Protein intakes were within the recommendations (NN 17.3%, NH 17.8%, and HH 18.3% of energy intake). Total fat intakes varied with only the NN and HN groups meeting the AMDR for total fat (34.4% and 30.6%, respectively). The other groups all consumed over the 35% of total energy cut off point for total fat intake. The HN group was the only group who consumed less than the recommended 12% of total energy intake as saturated fat per day (10.7%). The other groups consumed over the recommendation where 13.7%, 14.1%, 14.3%, and 12.6% of total energy intake was consumed as saturated fat in the NN, NH, HH and NL groups, respectively.

4.4 Top 40 Food Items

Total population

The 40 most frequently consumed foods reported in the NZWFFQ within the total study population are outlined in table 4.7. Twenty one of the 40 food items were from nutritious food groups, with 13 from the fruit and vegetable group, three from breads and cereals, three from low fat dairy products and two from eggs and nuts. No meat or poultry food items were present in the top 40 most frequently consumed foods.

Table 4.7 Top 40 foods consumed for the total population.

Ranking	Food item	Frequency (per day)*	Mean daily intake (g per person/d)	# respondents with daily consumption
1	Water	783.2	850	224
2	Oil, composite used in cooking	341.1	3.3	51
3	Coffee, brewed	173.8	189.4	73
4	Tea, black, infused, weak	170.4	190.1	71
5	Butter	168.4	3.1	41
6	Multigrain bread	159.6	28.6	63
7	Herbal tea	156.7	175.3	73
8	Lettuce	106.9	18.2	45
9	Oil as a dressing/sauce	105.1	2.5	59
10	White sugar	95.5	1.8	23
11	Lite milk added to drinks	85.4	32.2	55
12	Trim milk added to drinks	85.4	19.2	36
13	Apple	84.7	58	42
14	Onion	82.3	21	35
15	Coffee, espresso (30 mL)	79.5	12.2	38
16	Carrot	79.3	36.9	31
17	Yoghurt	78.4	54	35
18	Banana	77.8	57.6	41
19	Margarine as a dressing/sauce	77.4	1.7	36
20	Egg, chicken	76	18.9	16
21	Tomatoes	70.2	55.3	23
22	Cream crackers	69	6.7	23
23	Broccoli	68.3	33.9	17
24	Almonds	67.9	4.3	28
25	Margarine, Mono, 55% fat	65.9	1.3	26
26	Lollies	64.4	4.6	21
27	Margarine, Mono, 70% fat	61.5	1.3	22
28	Chocolate bar	60.2	12.7	25
29	Courgette	60	21.5	18
30	Cheese - edam	57.9	13.1	24
31	Capsicum	56.1	11.7	14
32	Peanut butter	55.2	3.7	19
33	Orange	54.3	34.8	16
34	Wholemeal bread	53.4	7.1	19
35	Tomato sauce	50.6	4	14
36	Diet soft drink	40.0	46.4	17
37	Plain biscuit	46.9	4.4	14
38	Avocado	46.2	11.5	10
39	Spinach	44.8	22.9	13
40	Potato	43.3	18	5

**Frequency per day indicates the number of times the food item is eaten per day by the total (n = 231) NZE women*

= Beverages

= Nutritional food items

= Discretionary food items

Body composition profile groups

The top 40 most frequently consumed foods within the three main BCP groups are outlined in table 4.8. The food items as previously mentioned for the NL and the HN BCP groups are not presented due to low sample sizes. Thirty of the 40 food items were present in all three BCP groups as being frequently consumed. Water and oil were the first and second items in all groups, similar to that of the total group. The HH group consumed water and oil for cooking more frequently than the other groups, although they were both ranked first and second, respectively in the BCP groups. They also used oil as a dressing more frequently than the other groups with this making the third top food in the HH group compared to the 8th and 9th food item in the NN and NH groups, respectively.

Fruit and vegetables were present in all BCP groups. The NN BCP group had 5 fruit and 6 vegetables in their top 40 foods, whereas the HH had 2 fruit and 8 vegetables and the NH 3 fruit and 7 vegetables. The HH BCP group was the only group to have an animal protein source in their top 40 food items, however all groups contained eggs as an alternative protein source. Additionally lite or trim milk and yoghurt were also present in all BCP groups. The highest ranking item from the breads and cereals food group was multigrain bread. This was ranked as the third most commonly consumed food in the NH group with this group having the highest frequency of consumption per day, consuming the most per day and having the most individuals consuming it per day.

All BCP groups contained discretionary items such as lollies and chocolate bars. Both these items ranked the highest in the HH BCP group, where they had the highest frequency of consumption, consumed the most per day and had the most individuals consuming on a daily basis. The HH group were also the only group to have diet soft drink in their top 40 food items.

Table 4.8 Top 40 foods compared between the three main body composition profile (BCP) groups.

Food item	BCP groups								
	NN (n = 63)			NH (n = 59)			HH (n = 88)		
	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI
Water (250 mL)	211.2 **(1)**	842.4	59	196.4 **(1)**	828.2	58	297.1 **(1)**	844.2	87
Oil used in cooking (5 mL)	115.8 **(2)**	3.6	16	87.8 **(2)**	3.6	15	287.8 **(2)**	3.3	20
Butter (1 tsp)	62.3 **(3)**	3.9	21	34.3 **(8)**	3.1	10	66.1 **(6)**	3	14
Coffee, brewed (1 cup)	54.7 **(4)**	196.9	22	39.6 **(6)**	175.3	16	67.9 **(5)**	203.3	31
Multigrain bread (1 slice)	51.0 **(5)**	33.7	19	53.5 **(3)**	35.2	25	44.1 **(10)**	22.1	15
White sugar (1 tsp)	15.5 **(30)**	3.3	6	25.3 **(10)**	1.8	10	-	-	-
Herbal tea (1 cup)	38.2 **(6)**	153.5	19	51.4 **(4)**	224.6	24	50.1 **(8)**	151.3	22
Black tea (1 cup)	33.5 **(7)**	141.2	15	51.1 **(5)**	223.7	22	71.5 **(4)**	207.6	28
Oil as a dressing/sauce (1 tsp)	32.3 **(8)**	2.8	20	31.9 **(9)**	2.9	20	193.1 **(3)**	2.2	17
Lettuce (0.5 cup)	27.0 **(10)**	16.8	12	21.2 **(14)**	16.2	8	49.2 **(9)**	20.3	23
Lite milk added to drinks (50 mL)	-	-	-	39.01 **(7)**	36	15	63.7 **(7)**	39	24
Carrot (0.5 cup)	25.9 **(12)**	40.5	12	15.9 **(27)**	28.5	4	26.7 **(22)**	35.6	9
Coffee, espresso (30 mL)	26.2 **(11)**	14.8	12	21.8 **(13)**	13.5	11	22.5 **(32)**	8.1	9
Apple (1 fruit)	23.0 **(15)**	59.7	14	16.5 **(26)**	46.1	6	33.6 **(11)**	58.3	14
Banana (1 fruit)	25.1 **(13)**	60.6	17	16.5 **(25)**	53.5	7	28.8 **(18)**	53.8	12
Margarine as a dressing/sauce (1 tsp)	23.1 **(14)**	1.9	13	20.7 **(15)**	1.9	9	25.2 **(26)**	1.4	11
Onion (0.25 cup)	19.3 **(19)**	16.8	8	19.1 **(18)**	18.9	7	30.7 **(15)**	22.3	7
Yoghurt (0.5 cup)	22.6 **(16)**	58.0	13	17.9 **(20)**	47.5	7	29.5 **(16)**	52.7	11
Trim milk added to drinks (50 mL)	17.8 **(24)**	15.0	9	25 **(11)**	21.9	10	33.1 **(12)**	19.4	12

Food items	BCP groups								
	NN (n = 63)			NH (n = 59)			HH (n = 88)		
	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI
Broccoli (0.5 cup)	19.1 **(20)**	35.5	4	15.7 **(28)**	27.1	4	25.5 **(25)**	34.9	6
Eggs (1 medium)	17.3 **(27)**	15.6	2	17.1 **(23)**	16.5	4	31.9 **(13)**	20.4	7
Margarine, Mono, 55% fat (5 mL)	22.0 **(17)**	1.6	10	13.7 **(33)**	1.1	3	27 **(21)**	1.4	12
Cream crackers (2 crackers)	17.4 **(26)**	6.6	6	18.9 **(19)**	7.3	5	24.4 **(27)**	6	8
Tomato (1 medium)	18.0 **(23)**	51.0	5	14.5 **(32)**	52.9	2	30.9 **(14)**	57.5	13
Lollies (2 items)	19.5 **(18)**	4.7	6	12.6 **(35)**	3.4	4	28.8 **(19)**	5.3	9
Peanut butter (1 tbsp)	18.4 **(22)**	4.2	8	-	-	-	20.9 **(34)**	3.6	6
Almonds (10 nuts)	17.5 **(25)**	3.8	9	19.6 **(17)**	4.6	8	25.6 **(23)**	4.5	9
Chocolate bar (1 small)	16.2 **(28)**	11.0	8	11.4 **(39)**	9.3	3	29.3 **(17)**	15.1	10
Margarine, Mono, 70% fat (5 mL)	19.0 **(21)**	1.4	6	-	-	-	28 **(20)**	1.5	9
Orange (1 fruit)	15.6 **(29)**	34.8	5	17.2 **(22)**	39.9	7			
Courgette (0.5 cup)	14.3 **(34)**	19.9	3	15.7 **(29)**	20.9	5	23.1 **(29)**	22.1	8
Cheese - edam (3 tbsp)	14.1 **(35)**	12.5	7	20.7 **(16)**	17.1	8	17.7 **(39)**	11	6
Honey (1 tsp)	13.2 **(38)**	1.6	5	-	-	-	-	-	-
Rolled oats (0.5 cup)	13.8 **(36)**	12.5	9	-	-	-	-	-	-
Wholemeal bread (1 slice)	14.9 **(32)**	7.1	4	16.6 **(24)**	8.9	7	19.4 **(35)**	6.6	7
Grapes (9 fruits)	14.6 **(33)**	10.6	3	-	-	-	-	-	-
Natural muesli (0.5 cup)	15.4 **(31)**	15.2	8	-	-	-	-	-	-
Fruit juice	13.4 **(37)**	62.5	5	-	-	-	-	-	-
Potato	12.8 **(39)**	19.1	2	-	-	-	-	-	-

Food items	BCP groups								
	NN (n = 63)			NH (n = 59)			HH (n = 88)		
	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI	Freq/d (ranking)	Mean intake (g/p/d)	# subjects with DI
Strawberries	12.6 **(40)**	18.2	5	-	-	-	-	-	-
Spinach (0.5 cup)	-	-	-	-	-	-	18.5 **(37)**	22.1	7
Seeds (sunflower)	-	-	-	11.6 **(37)**	1.9	3	-	-	-
Toasted sandwich (1 sandwich)	-	-	-	22.9 **(12)**	8.1	0	-	-	-
Lite milk added to cereal (125 mL)	-	-	-	17.8 **(21)**	44.9	12	-	-	-
Plain biscuit (2 biscuits)	-	-	-	15.5 **(30)**	6	7	17.5 **(40)**	4.1	4
Capsicum (0.5 of a whole)	-	-	-	13.5 **(34)**	10.5	2	25.5 **(24)**	13.2	8
Tomato sauce (1 tbsp)	-	-	-	-	-	-	24.3 **(28)**	5.3	8
Cheese – cheddar (3 tbsp)	-	-	-	-	-	-	23.0 **(30)**	13.2	7
Avocado (0.25 of a fruit)	-	-	-	14.6 **(31)**	13.8	4	-	-	-
Chocolate biscuit (2 biscuits)	-	-	-	11.9 **(36)**	4.8	3	-	-	-
Margarine, Poly, 60% fat (5 mL)	-	-	-	11.5 **(38)**	0.9	5	-	-	-
Muesli bar (1 bar)	-	-	-	11.2 **(40)**	7.2	4	-	-	-
Diet soft drink (1 cup)	-	-	-	-	-	-	22.9 **(31)**	70.8	10
Frozen mixed vegetables (0.5 cup)	-	-	-	-	-	-	21.6 **(33)**	25.8	4
Marmite (1 tsp)	-	-	-	-	-	-	19.1 **(36)**	1.5	5
Chicken breast (125g)	-	-	-	-	-	-	18.4 **(38)**	31.3	4

= Beverages
= Nutritional food items
= Discretionary food items

NN = Normal BMI (18.5 – 24.9 kg/m^2), normal BF% (22 – 29.9%);
NH = Normal BMI, high BF% (≥ 30%);
HH = High BMI (≥ 25.0), high BF%

Freq/d = Frequency per day;
g/p/d = grams per person per day;
DI = Daily intake

n = number

***Bold items** = new food items not in the top 40 foods identified for the total NZE population*

4.5 Dietary Pattern Analysis

Dietary patterns were identified using the FFQ data obtained from the total NZE population (n=231). Principal components factor analysis was used to analyse the data which identified four dietary patterns. Food items that loaded on each of the factors are outlined in table 4.9.

The four patterns that were identified were named as follows:

- Snacking pattern (pattern 1) – This pattern was characterised by high loadings on 12 items which are commonly consumed as snacks, especially peanut butter, margarine, sweet spreads, cakes and biscuits and sweet and savoury snack foods e.g. chocolate and potato chips. It was also characterised by negative loadings on green vegetables, red meats and egg and egg dishes.

- Energy-dense meat pattern (pattern 2) – This pattern was characterised by high loadings on 15 items which were either high in energy or meat products such as red, white and processed meats, pudding, and crumbed and deep fried food items e.g. crumbed and battered fish. It was also characterised by negative loadings on high calcium milk, yoghurt, soy products and water.

- Fruit and vegetable pattern (pattern 3) – This pattern was characterised by high loadings on 7 items all of which were fruits and vegetables. It was also characterised by negative loadings on coffee.

- Healthy pattern (pattern 4) – This pattern was characterised by high loadings on 9 items including water, whole grains, and meat alternatives such as fish and seafood, legumes, and nuts and seeds. It was also characterised by negative loadings on white and brown breads, sweetened cereals and fruit juice.

Table 4.9 Factor loading matrix for the four dietary patterns identified in NZE women (n=231).

	Dietary patterns			
	1	**2**	**3**	**4**
Full fat milk	-	-	-	-
Low fat milk	-	-	-	-
High calcium milk	**.284**	-.238	-	-
Sweetened milk products	-	**.297**	-	-
Yoghurt	-	-.214	-	-
High fat cheese	-	**.361**	-	-
Low fat cheese	**.303**	-	-	-
Apple, Banana, Orange	-	-	**.424**	-
Other fruit	-	-	**.568**	-
Tomatoes	-	-	**.476**	-
Dark-yellow vegetables	-	-	**.628**	-
Green vegetables	-.249	-	**.588**	-
Other non-starchy vegetables	-	-	**.673**	-
Potatoes	-	**.402**	-	-
Starchy vegetables	-	-	**.593**	-
White breads	-	**.480**	-	-
Discretionary breads		**.422**	-	-
Crackers	**.280**	-	-	-
Brown breads	**.384**	-	-	-.225
Refined grains	-	**.390**	-	-
Wholegrain	-	-	-	**.583**
Non sweetened cereals	-	-	-	-
Sweetened cereals	-	-	-	-.291
Red meats	-.231	**.609**	-	-
White meats	-	**.495**	-	-
Processed meats	-	**.577**	-	-
Fish and seafood	-	-	-	**.502**
Egg and egg dishes	-.233	-	-	**.293**
Legumes	-	-	-	**.546**
Soy products	-	-.248	-	**.398**
Peanut butter and peanuts	**.549**	-	-	-
Nuts and seeds	-	-	-	**.411**
Coconut fats	-	-	-	**.462**
Margarine	**.538**	-	-	-
Creamy dressings	-	**.297**	-	-
Sauces	-	**.396**	-	-
Sweet spreads	**.572**	-	-	-
Savoury spreads	**.336**	-	-	-
Cakes and biscuits	**.674**	-	-	-
Pudding	-	**.565**	-	-
Sweet snack foods	**.477**	-	-	-
Savoury snack foods	**.531**	-	-	-
Crumbed and deep fried	-	**.544**	-	-
Fast food	-	-	-	-
Fruit juice	-	-	-	-
Fruit and other drinks	-	**.328**	-	-
Tea	**.206**	-	-	-
Coffee	-	-	-.245	-
Beer	-	-	-	**.234**
Wine	-	-	-	-
Water	-	-.279	-	**.430**
Other alcoholic beverages	-	**.312**	-	-

Dietary patterns based on analysis of FFQ data from 231 NZE women;
Factors identified based on factor loadings > 0.2;
Cross-loadings removed from factors;
Food items with no loadings had loadings < 0.2
Pattern 1: 'Snacking' pattern;
Pattern 2: 'Energy-dense meat' pattern;
Pattern 3: 'Fruit and Vegetable' pattern;
Pattern 4: 'Healthy' pattern

Cronbach's α indicated that there was a moderate inter-item reliability (table 4.10) which was improved for each dietary pattern after the removal of white sugar, and drinks in pattern 1, oats in pattern 2, and oil-based dressings, fats and soy milk in pattern 4.

Table 4.10 Cronbach's α score for each of the dietary patterns.

Pattern	Original Cronbach's α	New Cronbach's α	Items removed
1	0.619	0.639	White sugar, diet drinks
2	0.634	0.634	*NA* – highest value
3	0.641	0.648	Oats
4	0.252	0.431	Oil and oil-based dressings, fats, soy milk

NA = Not applicable;
These patterns explained 6.9, 6.8, 5.6 and 4.8% of variation in food intakes, respectively

Each dietary pattern was then broken down into tertiles (T1, T2, T3) for further analysis. Those who scored highly on the pattern, reflected high consumption of those with positive factor loadings, and low consumption of those foods with negative factor loading, and were categorised as tertile 3.

In the 'snacking' pattern, there was a statistically significantly difference in age ($F(2,228) = 3.36$, $P = 0.036$) between tertiles 1 and 3. Women who followed the 'snacking' pattern more closely were older compared to those in lower 'snacking' pattern tertiles.

In the 'energy-dense meat' pattern, there was also a statistically significant difference between the age (32.8 years ± 8.2, 32.9 years 8.1, 30.0 years ± 8.3) and BMI (24.6 kg/m^2 ± 4.2, 24.4 kg/m^2 ± 4.0, 26.4 kg/m^2 ± 6.7) between tertiles one, two and three, respectively.. Women who followed the 'energy-dense meat' pattern were younger compared to those in the lower 'energy-dense meat' pattern tertiles. Additionally women who followed the 'energy-dense meat' pattern had a lower BMI compared to those in the lower 'energy-dense meat' pattern tertiles. No other patterns showed a significant association with age, BMI or BF% (table 4.11).

Table 4.11 Age, body mass index (BMI) and body fat percentage (BF%) characteristics of the tertiles in the dietary patterns for the NZE women (n = 231).

	Age (years)	*P-value*	**BMI (kg/m^2)**	*P-value*	**BF%**
Pattern 1					
T1	31.9 ± 8.7*		24.2 ± 3.7		31.9 ± 7.3
T2	29.9 ± 8.0	0.026	25.2 ± 4.8		32.1 ± 8.4
T3	33.9 ± 7.9*		25.9 ± 6.5		33.7 ± 8.5
Pattern 2					
T1	32.8 ± 8.2*	0.048	24.6 ± 4.2*	0.036	32.2 ± 7.4
T2	32.9 ± 8.1		24.4 ± 4.0		31.4 ± 7.2
T3	30.0 ± 8.3*		26.4 ± 6.7*		34.3 ± 9.2
Pattern 3					
T1	31.7 ± 7.8		24.8 ± 4.4		33.2 ± 7.2
T2	31.1 ± 8.4		24.4 ± 4.3		31.5 ± 7.2
T3	32.9 ± 8.6		26.2 ± 6.4		33.1 ± 9.5
Pattern 4					
T1	32.2 ± 8.6		25.2 ± 4.8		33.7 ± 7.5
T2	31.6 ± 8.6		25.5 ± 5.6		33.0 ± 8.1
T3	31.9 ± 7.6		24.8 ± 5.1		31.1 ± 8.4

Pattern 1 = Snacking;
Pattern 2 = Energy-dense meat;
Pattern 3 = Fruit and vegetables;
Pattern 4 = Healthy

Values are means ± standard deviations;
T1, T2, T3 = tertiles of dietary pattern score
** = statistically significant (P < 0.05) (ANOVA analysis within each pattern between tertiles);*

When age, BMI and BF% were categorised into groups, age remained significantly associated with dietary pattern 2 only (χ^2 (4) = 10.132, P <0.038). A significantly higher proportion of women aged 16 to 24 years were in the highest tertile of the 'energy-dense meat' pattern reflecting higher consumption of those foods compared to women 36 to 45 years of age (table 4.12).

There was no association between 'snacking' pattern and BMI and BF% groups indicating that women consume foods from this pattern regardless of their body composition (table 4.12). In comparison, a higher proportion of women in the low BF% (<22%) group had higher consumption of food items from the 'fruit and vegetable' and 'healthy' patterns.

Table 4.12 Socio-demographic characteristics of the NZE women in the tertiles of each dietary pattern.

		Dietary patterns											
		Snacking pattern			Energy-dense meat pattern			Fruit and vegetables pattern			Healthy pattern		
Characteristics	**n**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
Age (years)													
16-24	56	39.3	1.8	58.9	26.8	23.2	50.0*	26.8	44.6	28.6	33.9	33.9	32.1
25-35	89	33.7	3.4	62.9	32.6	37.1	30.3	39.3	30.3	30.3	32.6	33.7	33.7
36-45	86	29.1	0	70.9	38.4	36.0	25.6	31.4	29.1	39.5	33.7	33.7	32.6
BMI (kg/m^2)													
18.5-24.99	140	29.3	2.9	67.9	35.7	36.4	27.9	34.3	33.6	32.1	31.4	33.6	35.0
25.0-29.99	61	39.3	0	60.7	34.4	31.1	34.4	32.8	41.0	26.2	39.3	29.5	31.1
≥ 30.0	30	40.0	0	60.0	20.0	23.3	56.7	30.0	16.7	53.3	30.0	43.3	26.7
BF%													
< 22%	18	33.3	0	66.7	33.3	44.4	22.2	11.1	44.4	44.4	16.7	22.2	61.1
≥22-29.9%	66	30.3	4.5	65.2	34.8	30.3	34.8	37.9	28.8	33.3	30.3	39.4	30.0
≥ 30%	147	34.7	0.7	64.6	32.7	33.3	34.0	34.0	34.0	32.0	36.7	32.7	30.6

Values are percentages of the total number in that group; N = number of participants;
T1, T2, T3 = tertiles of dietary pattern score;
** = proportions across tertiles within the dietary pattern differed significantly (P = 0.035; significant = P<0.05) (Chi-square analysis)*

4.6 Diet Quality

The 'snacking' pattern had significantly different intakes of 18 out of 29 nutrients across the tertiles. This dietary pattern had moderate intakes of all nutrients compared to the other patterns (table 4.13).

The 'energy-dense meat' pattern had significantly different intakes of all nutrients except vitamin A and selenium across tertiles. Women with the highest and lowest dietary scores in this pattern had the highest and lowest intakes of energy, protein, carbohydrate, total fat, saturated fat, sugar, iron and zinc respectively (table 4.13). The nutrient and energy density of this pattern is changed considerably depending on the extent to which it is followed. Considering the food items associated with this pattern these findings were expected and thus confirm the naming of this pattern.

Across tertiles of scores on the 'fruit and vegetable' pattern, there were significantly different intakes for 18 out of 29 nutrients. Women with the highest and lowest dietary scores in this pattern had the highest and lowest intakes of vitamin C and vitamin A, respectively (table 4.13).

The 'healthy' pattern had significantly different intakes between the tertiles in 17 out of 29 nutrients. Women with the highest and lowest dietary scores in this pattern had the highest and lowest intakes of vitamin E, and those who had moderate scores in this pattern had the lowest intake of vitamin D, whereas those in tertile 3 had the highest intakes of vitamin D (table 4.13).

Table 4.13 Nutrient intakes within the dietary pattern tertiles identified from the NZWFFQ among NZE women.

	EAR	Snacking pattern			Energy-dense meat pattern			Fruit and vegetable pattern			Healthy pattern		
		T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Energy (kJ)	Na	8515.5 ±2792.8	9099.9 ±2862.1	9420.4 ±3204.1	7058.7 ± 2106.6	8773.9 ± 1973.6	11142.8 ± 3057.6	8469.5 ± 3033.1	8832.7 ± 2617.3	9673.1 ± 3062.8	9158.7 ± 3368.9	8393.3 ± 2882.7	9437.0 ± 2432.6
P-value		*0.159*			*0.000**			*0.033**			*0.073*		
Protein (g)	Na	91.6 ±33.2	96.8 ±31.0	96.8 ±34.3	78.5 ± 25.8	91.4 ± 22.1	116.5 ± 37.3	87.8 ± 31.5	94. 5 ± 32.7	104.0 ± 33.3	93.8 ± 35.7	87.8 ± 29.5	104.9 ± 31.8
P-value		*0.532*			*0.000**			*0.009**			*0.005**		
Total fat (g)	Na	83.7 ±36.3	84.7 ±28.5	88.2 ±34.9	64.6 ± 23.6	83.8 ± 25.0	107.9 ± 34.6	85.0 ± 36.6	82.4 ± 30.2	89.0 ± 32.5	86.5 ± 37.5	76.7 ± 28.0	93.3 ± 31.8
P-value		*0.674*			*0.000**			*0.469*			*0.007**		
SF (g)	Na	34.8 ±18.9	33.9 ±14.1	34.8 ±16.2	24.2 ± 10.4	33.5 ± 11.6	45.4 ± 18.2	35.0 ± 18.1	33.2 ± 13.3	34.8 ± 17.2	36.6 ± 19.1	30.6 ± 12.7	35.8 ± 16.0
P-value		*0.937*			*0.000**			*0.753*			*0.044**		
PUFA (g)	Na	11.5 ±4.2	12.5 ±4.4	13.7 ±5.5	10.7 ± 4.6	12.4 ± 4.3	14.8 ± 4.7	12.1 ± 4.7	12.0 ± 4.7	13.8 ± 5.0	11.6 ± 4.5	11.3 ± 4.1	15.0 ± 5.0
P-value		*0.013**			*0.000**			*0.038**			*0.000**		
MUFA (g)	Na	28.2 ±11.6	28.7 ±9.6	30.0 ±11.9	22.4 ± 8.6	28.6 ± 9.0	36.1 ± 11.1	28.9 ± 12.3	28.0 ± 10.7	30.3 ± 10.3	28.8 ± 12.0	26.2 ± 9.6	32.2 ± 10.9
P-value		*0.580*			*0.000**			*0.439*			*0.003**		
Cholesterol (mg)	Na	278.5 ±164.2	300.2 ±139.7	284.1 ±147.1	233.6 ± 127.8	282.9 ± 141.0	355.1 ± 189.4	272.9 ± 171.3	281.3 ± 155.4	317.3 ± 158.2	262.8 ± 118.0	246.1 ± 100.0	364.2 ± 219.0
P-value		*0.651*			*0.000**			*0.197*			*0.000**		
CHO (g)	Na	207.2 ±75.4	234.7 ±89.3	245.7 ±96.7	177.7 ± 59.7	221.4 ± 71.6	284.1 ± 95.4	207.2 ± 87.8	225.0 ± 69.1	250.9 ± 100.6	239.4 ± 93.0	219.3 ± 91.0	224.5 ± 80.0
P-value		*0.021**			*0.000**			*0.008**			*0.344*		
Sugars (g)	Na	109.6 ±45.0	129.4 ±59.6	126.9 ±55.5	96.7 ± 40.8	117.2 ± 44.9	148.3 ± 60.8	105.9 ± 52.8	115.8 ± 40.5	140.4 ± 60.7	125.8 ± 60.6	114.5 ± 52.8	121.9 ± 47.1
P-value		*0.047**			*0.000**			*0.000**			*0.420*		
Alcohol (g)	Na	7.4 ±8.7	6.3 ±7.5	6.2 ±7.4	5.9 ± 8.3	7.5 ± 7.9	6.9 ± 7.5	7.4 ± 8.8	7.4 ± 8.3	5.5 ± 6.4	6.1 ± 8.3	6.7 ± 7.9	7.5 ± 7.6
P-value		*0.425*			*0.459*			*0.227*			*0.567*		
Dietary fibre (g)	Na	26.4 ±8.5	30.5 ±9.2	31.8 ±11.4	27.3 ± 9.6	29.1 ± 9.2	32.2 ± 10.6	22.8 ± 7.0	28. 9 ± 7.4	36.8 ± 9.9	26.6 ± 9.6	28.7 ± 9.9	33.2 ± 9.4
P-value		*0.002**			*0.008**			*0.000**			*0.000**		
Thiamin (mg)	0.9	1.5 ±0.9	1.6 ±0.8	1.8 ±0.8	1.3 ± 0.8	1.6 ± 0.7	2.0 ± 0.9	1.5 ± 0.9	1.6 ± 0.8	1.9 ± 0.8	1.6 ± 0.7	1.7 ± 1.0	1.6 ± 0.6
P-value		*0.164*			*0.000**			*0.008**			*0.366*		
Riboflavin (mg)	0.9	2.5 ±1.1	2.7 ±1.4	2.5 ± 1.2	2.2 ± 1.1	2.5 ± 1.0	3.0 ± 1.5	2.4 ± 1.2	2.4 ± 0.9	2.8 ± 1.5	2.7 ± 1.5	2.4 ± 1.2	2.7 ± 0.9

	EAR	Snacking pattern			Energy-dense meat pattern			Fruit and vegetable pattern			Healthy pattern		
		T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
P-value			*0.476*			*0.000**			*0.050*			*0.226*	
Niacin (mg)	11	21.9 ±9.8	22.7 ±11.4	22.7 ±9.9	18.7 ± 7.3	22.3 ± 8.1	26.7 ± 13.2	20.6 ± 9.8	21.2 ±8.0	25.8 ±12.2	22.3 ±12.6	21.2 ±9.5	24.3 ±8.4
		T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
P-value			*0.856*			*0.000**			*0.003**			*0.173*	
Vitamin C (mg)	30	142.5 ±82.9	168.2 ±84.5	165.3 ±86.3	140.6 ± 77.5	154.5 ± 64.3	175.0 ± 102.6	103.6 ± 46.9	153.4 ± 61.9	213.2 ± 95.6	143.2 ± 84.8	153.4 ± 85.0	173.8 ± 79.7
P-value			*0.120*			*0.037**			*0.000**			*0.070*	
Vitamin D (µg)	Na	4.2 ±2.5	4.8 ±2.6	4.5 ±2.4	4.0 ± 2.4	4.3 ± 2.5	5.2 ± 2.6	4.5 ± 2.9	4.3 ± 2.3	4.8 ± 2.3	4.4 ± 2.7	3.9 ± 2.1	5.3 ± 2.5
P-value			*0.329*			*0.006**			*0.520*			*0.003**	
Vitamin E (mg)	Na	12.2 ±4.8	13.5 ±4.8	14.2 ± 5.2	12.1 ± 5.3	12.9 ± 4.4	14.9 ± 4.8	11.7 ± 4.5	12.5 ± 4.5	15.6 ± 5.1	11.6 ± 4.3	11.8 ± 3.8	16.5 ± 5.2
P-value			*0.035**			*0.001**			*0.000**			*0.000**	
Vitamin B6 (mg)	1.1	2.5 ±2.0	2.7 ±2.2	2.6 ±1.9	2.1 ± 0.9	2.5 ± 2.0	3.1 ± 2.7	2.3 ± 2.1	2.4 ± 1.0	3.1 ± 2.6	2.7 ± 2.9	2.3 ± 1.7	2.8 ± 1.0
P-value			*0.859*			*0.009**			*0.014**			*0.373*	
Vitamin B12 (µg)	2.0	4.7 ± 2.9	4.9 ±2.7	4.5 ±2.4	3.7 ± 2.0	4.5 ± 1.9	6.2 ± 4.0	4.5 ± 3.2	4.6 ± 2.7	5.3 ± 3.0	4.5 ± 2.7	4.3 ± 2.3	5.6 ± 3.6
P-value			*0.569*			*0.000**			*0.242*			*0.009**	
Total-folate (µg)	320	410.6 ±172.1	424.7 ±134.3	451.4 ±174.5	381.8 ± 142.8	440.7 ± 162.9	463.7 ± 172.3	371.1 ± 140.2	405.6 ± 151.1	509.5 ± 165.1	416.3 ± 167.9	428.8 ± 175.5	441.3 ± 144.2
P-value			*0.282*			*0.005**			*0.000**				*0.640*
Vitamin A (µg)	500	1351.9 ±444.8	1637.8 ±727.1	1672.8 ±904.0	1407.3 ± 685.3	1568.8 ± 727.5	1667.5 ± 751.8	1171.6 ± 506.2	1504.9 ± 472.6	1967.0 ± 892.2	1384.6 ± 618.6	1570.0 ± 805.0	1690.5 ± 720.2
P-value			*0.011**			*0.081*			*0.000**			*0.031**	
Sodium (mg)	Na	2406.2 ±959.9	2458.3 ±988.7	2608.4 ±1132.2	1832.9 ± 691.8	2386.9 ± 619.5	3280.0 ± 1124.1	2469.2 ± 1127.4	2438.9 ± 871.9	2591.8 ± 1077.9	2631.7 ± 1249.9	2339.6 ± 914.7	2531.0 ± 872.6
P-value			*0.450*			*0.000**			*0.623*			*0.200*	
Potassium (mg)	Na	3465.3 ±1076.9	3932.0 ±1273.3	3903.7 ±1305.0	3420.3 ± 1195.5	3686.7 ± 948.2	4173.7 ± 1398.4	3182.2 ± 973.7	3630.3 ± 1045.2	4468.2 ± 1294.5	3570.2 ± 1273.5	3517.8 ± 1168.9	4201.5 ± 1139.7
P-value			*0.031**			*0.000**			*0.000**			*0.001**	
Magnesium (mg)	255	365.8 ±112.0	408.6 ±125.2	413.9 ±135.7	362.4 ± 134.8	388.7 ± 106.3	436.7 ± 123.8	348.0 ± 107.9	391.6 ± 122.5	448.2 ± 126.1	367.5 ± 122.1	361.1 ± 111.7	460.5 ± 118.7
P-value			*0.033**			*0.001**			*0.000**			*0.000**	
Calcium (mg)	840	1146.2 ±493.3	1254.6 ±532.2	1175.2 ±512.3	1060.9 ± 536.4	1162.6 ± 422.7	1355.1 ± 531.7	1150.4 ± 545.8	1138.6 ± 419.6	1289.6 ± 553.2	1211.4 ± 589.1	1112.4 ± 489.2	1256.6 ± 443.1
P-value			*0.399*			*0.001**			*0.126*			*0.202*	
Phosphorus (mg)	580	1616.3 ± 543.4	1760.9 ±565.1	1748.3 ±590.3	1482.3 ± 552.3	1643.5 ± 393.6	2006.8 ± 603.7	1561.8 ± 536.7	1676.7 ± 533.2	1894.0 ± 583.7	1663.2 ± 610.5	1567.6 ± 534.7	1906.2 ± 500.2

	EAR	Snacking pattern			Energy-dense meat pattern			Fruit and vegetable pattern			Healthy pattern		
		T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
P-value		*0.217*			*0.000**					*0.001**	*0.001**		
Iron (mg)	8	11.5 ±3.8	12.6 ±3.6	13.1 ±4.3	10.5 ± 3.3	12.1 ± 3.2	14.6 ± 4.4	10.9 ± 3.7	12.1 ± 3.9	14.2 ± 3.7	11.6 ± 4.0	11.8 ± 3.9	14.0 ± 3.8
P-value		*0.035**			*0.000**			*0.000**			*0.000**		
Zinc (mg)	6.5	11.3 ±4.2	11.9 ±3.8	12.0 ±4.3	9.4 ± 3.0	11.3 ± 2.8	14.6 ± 4.7	10.7 ± 4.1	11.7 ± 4.0	12.9 ± 4.2	11.8 ± 4.5	10.8 ± 3.6	12.8 ± 4.2
		T1	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
P-value		*0.541*			*0.000**			*0.006**			*0.011**		
Selenium (µg)	50	77.1 ±40.4	87.9 ±68.0	82.9 ±42.7	79.1 ± 69.2	76.0 ± 36.3	93.0 ± 44.9	75.1 ± 66.8	82.2 ± 45.3	90.8 ± 40.5	62.6 ± 28.1	69.5 ± 30.2	116.5 ± 70.0
P-value		*0.433*			*0.099*			*0.174*			*0.000**		

Values are mean intakes ± standard deviation;

** = statistically significant (P < 0.05) (ANOVA analysis within each pattern between tertiles);*

EAR = Estimated average requirements (National Health Medical Research Council, 2005)

T1, T2, T3 = tertiles of dietary pattern score

NZWFFQ = New Zealand Women's Food Frequency Questionnaire

MUFA = Monounsaturated fat;

PUFA = Polyunsaturated fat;

SF = Saturated fat;

CHO = Carbohydrate

There were some significant differences between the macronutrient distributions in each of the dietary patterns (table 4.13). The macronutrient distributions were not significantly different across the tertiles of the 'snacking' pattern scores. Women who were in tertile 3 of the 'energy-dense meat' pattern had significantly higher protein and saturated fat intakes compared to those in tertiles 1 and 2. This suggests that women who closely follow this pattern may consume higher amounts of food items such as red meat or high fat cheese compared to those who follow it less closely. The 'fruit and vegetable' pattern had significantly different carbohydrate intakes between the tertiles; with those in tertile 3 having significantly higher intakes compared to women in tertiles 1 and 2. It is likely that these women have a higher fruit or starchy vegetable consumption compared to the women who follow the pattern less closely. The 'healthy' pattern had significantly higher intakes of protein and total fat in tertile 3 compared to tertiles 1 and 2. This suggests that women in tertile 3 consume more meat alternatives as protein sources and use more coconut oil, nuts and seeds in their cooking.

None of the dietary patterns met all AMDR's (table 4.14). All of the dietary patterns had mean protein intakes within the recommended range of 15 -25% of total energy intake. The carbohydrate intakes in all of the dietary patterns fell below the recommended range of 45 – 65% of total energy intake. The intake of total fat varied with half of the tertiles meeting the AMDR (20 – 35% of total energy intake), although these tertile intakes were at the higher end of the recommendations. All tertiles exceeded the AMDR of less than 12% of total energy intake for saturated fat. Overall, when analysing tertile 3 as the highest users of the dietary pattern, the 'fruit and vegetable' pattern showed the highest protein consumption and the 'energy-dense meat' pattern had the highest saturated fat intakes. Moderate intakes of carbohydrate and total fat were seen in tertile 3 of all the patterns as the highest intakes were present in tertile 1 of the 'healthy' pattern and tertile 1 of the 'fruit and vegetable' pattern for carbohydrate and total fat, respectively.

Table 4.14 Macronutrient distribution between dietary pattern tertiles.

Macronutrient	Snacking pattern			Energy-dense meat pattern			Fruit and vegetable pattern			Healthy pattern		
(% of EI)	T1	T2	**T3**	T1	T2	**T3**	T1	T2	**T3**	T1	T2	**T3**
Protein	18.5 ± 3.0	18.3 ± 3.3	**17.8 ± 3.8**	19.1 ± 3.8*	17.9 ± 3.4*	**17.8 ± 2.9***	17.9 ± 3.7	18.3 ± 2.9	**18.6 ± 3.7**	17.6 ± 2.9*	18.1 ± 3.3*	**19.2 ± 3.9***
Carbohydrate	40.2 ± 7.8	42.1 ± 6.7	**42.6 ± 7.3**	41.5 ± 7.1	41.2 ± 8.5	**41.9 ± 7.0**	40.1 ± 8.1	42.1 ± 6.2	**42.3 ± 8.1**	43.2 ± 5.8*	42.5 ± 6.4*	**38.7 ± 9.3***
Fat	35.9 ± 7.6	34.5 ± 5.9	**34.5 ± 5.6**	33.8 ± 6.3	35.3 ± 6.9	**35.9 ± 6.3**	36.8 ± 6.5*	34.2 ± 5.3*	**34.1 ± 7.3***	34.5 ± 5.6*	33.8 ± 5.4*	**36.7 ± 7.9***
Saturated fat	14.6 ± 4.6	13.6 ± 2.9	**13.4 ± 3.0**	12.5 ± 3.0*	14.1 ± 3.4*	**15.0 ± 3.9***	14.8 ± 3.7*	13.7 ± 2.8*	**13.1 ± 4.1***	14.3 ± 3.6	13.3 ± 2.7	**13.9 ± 4.4**

Values are means ± standard deviation;
** = Statistically significant (P<0.05) (ANOVA analysis within each pattern between tertiles);*
T1, T2, T3 = tertiles of dietary pattern score;
EI = Energy intake

Chapter 5 Discussion

Analysing dietary patterns within a population is increasing in popularity to assess diet-disease relationships. In contrast with a single nutrient approach, it analyses the whole diet giving insight to a population's eating patterns. From this, dietary advice can be given to improve nutrition and health outcomes. This study sought to explore the dietary intake and associated eating patterns of New Zealand European (NZE) women participating in the wider EXPLORE study. The objectives were to explore the dietary intakes of NZE women, identify eating patterns which are the strongest predictors of increased body fat, and explore differences in macronutrient profiles and micronutrient intakes between BCP groups. The findings demonstrate that several dietary patterns can be identified within this population, which explain some of the differences seen between individual body compositions. Other factors such as portion size, socio-economic status and food availability may play a role.

5.1 Participant Characteristics

The 231 NZE women involved in this study had on average a normal (18.5 – 24.9 kg/m^2) BMI (24 kg/m^2) and a high (≥30%) BF% (32.6%) body composition (World Health Organisation, 2014a, Oliveros, 2014). The 2013/14 New Zealand National Health Survey showed the mean BMI of NZE women to be 27.5 kg/m^2, indicating that the majority of women are overweight (Ministry of Health, 2014b). The 2014/15 National Health Survey also showed that 30.6% of NZE women have a BMI ≥30 kg/m^2 indicating obesity (Ministry of Health, 2015b). This percentage has progressively increased since the 2006/07 National Health survey where 24.6% of NZE women were obese (Ministry of Health, 2015b). This cohort of women may therefore not be a representative sample of the New Zealand population (Ministry of Health, 2014a). The study attracted many women who were interested in health and nutrition and also those who were a part of sports clubs and teams. It is possible that these women eat a healthier diet and participate in physical activity more regularly than others in the population thus leading to a lower BMI for this cohort of women.

When comparing the NN, NH and HH BCP groups, a positive relationship was present between age, BMI and BF%. The NN group contained on average the youngest women by 5.6 years with a mean age of 28.2 years compared to the NH group (33.1 years) and the HH group (33.8 years). The NN BCP group also had women with on average the lowest BMI (21.4 kg/m^2) and BF% (25.8%) compared to the NH BCP group (23.0 kg/m^2, 33.4%) and the HH BCP group (28.6 kg/m^2, 39.1%). This shows that there is a positive trend between increasing age and adiposity.

The 2014/15 National Health Survey also showed similar results where the percentage of NZE women classed as obese increased from 20.1% in women 15 to 24 years, 27% in women 25 to 34 years and 32.6% in women 25 to 34 years (Ministry of Health, 2015b). The difference in BMI between the NN and HH BCP groups was significant, as was BF% between all BCP groups apart from the HN's. These differences were expected as the participants were recruited and categorised based on their individual body compositions and allocated into the relevant groups. Age was not significantly different between any of the BCP groups which was also expected because the women were recruited in approximately equal numbers within age categories (16-24, 25-35, 36-45). This indicates that there is a significant difference between body compositions in women with similar BMIs. Although the NL and HN BCP groups were not originally body compositions recruited for, several participant body compositions changed category after the ADP analysis due to the increased sensitivity by this machine and strict testing protocol, compared to the BIA machine used for screening without any of the testing requirements. These women were therefore included in the analysis.

5.2 Dietary Intake Analysis

5.2.1 Total population

On average, the women's dietary intake met the Ministry of Health's EAR's for all micronutrients. This was also true for the RDI's and the AI's apart from vitamin D and iron. The EAR is set at a level which is sufficient to meet the nutrient needs of at least half of healthy individuals and are the lowest level of which is required to maintain a defined level of nutriture in an individual (Yates, 1998). These values are used to determine the adequacy of nutrient intakes in population groups, whereas the RDI is set at two standard deviations above the EAR and is set an intake level that exceeds the requirements of 97-98% of healthy individuals (Gibson, 2005). It is therefore not usually used for group analysis and is more appropriate for assessing an individual's nutrient intake and if, met indicates that that individual has a low risk of nutrient deficiency (National Health Medical Research Council, 2005, Gibson, 2005). For some nutrients the RDI as well as the EAR were compared to the intakes of these women. Some nutrients were consumed in high amounts and it was therefore interesting to analyse these intakes using both the EAR and RDI values.

It was expected that the average nutrient intakes of the NZE women recruited in this study would meet the EAR guidelines because the women included in this study were well nourished with no signs of nutrient deficiency, and were free of chronic disease. It was also expected that a proportion of women would fall below the RDI values for several nutrients because the RDI

values exceed the actual nutrient requirements of nearly all healthy individuals and therefore it will always result in an overestimation of the proportion of the group with inadequate nutrient intakes (National Health Medical Research Council, 2005, Gibson, 2005). It is important to identify a point at which nutrient intakes below the EAR and RDI are a concern. Gibson (2005) states that if the intake is below the EAR there is a 50% probability of inadequate intake in that group. This indicates that any intake below the EAR reference values would be concerning and needs to be addressed. Some nutrients do not have an EAR value and therefore their intake needs to be compared against the RDI. As the proportion of the group below the RDI is likely to be exaggerated as stated above, a cut-off value has been outlined by Gibson (2005) which allows approximation of inadequate intakes. It states that 77% of the RDI should be met by individuals to ensure nutrient adequacy and anything below indicates insufficient nutrient intakes (Gibson, 2005).

Iron

The dietary iron intakes in the NZE women met the EAR but not the RDI. This indicates that on a group level at least half of the women are meeting their iron requirements per day; with only 3.4% of NZE women below the EAR however on an individual level iron intakes are poor. The majority of women (91.7%) were consuming iron intakes (12.6 mg/d) below the RDI (18 mg/d). These findings are similar to that of the 2008/09 National Nutrition Survey with an estimated 34.2% of women aged 15 to 18 years and 15.4% aged 31 to 50 years having inadequate iron intakes (University of Otago and Ministry of Health, 2011). Similar results have also been seen in premenopausal women elsewhere, with inadequate iron intakes prevalent in the USA and Canada (Gadowsky *et al.*, 1995, Stang *et al.*, 2000, Cooper *et al.*, 2006). Iron deficiency is the most common nutrient deficiency worldwide and although many dietary factors such as vitamin C, phytates, calcium and polyphenols modify iron absorption, inadequate dietary iron intake is the main cause of iron deficiency (Swanson, 2003, Beck, 2014, Coad and Pedley, 2014). Conversely, Kennedy and Meyers (2005) found American women to have adequate intakes above the EAR. The premenopausal women in a study by Mazess (1991) also had iron intakes above the EAR showing that intakes are very variable between different populations.

Although the majority of women in this study did not meet the RDI this was expected as the value tends to overestimate the proportion of women with poor intakes. Kennedy and Meyers (2005) found that if the RDI value was used for comparison the rate of insufficient iron intake would be a lot higher compared to when using the EAR value. More importantly is that all women meet the EAR as well as at least 77% of the RDI to ensure minimal risk of deficiency. The majority of the women (94%) met the EAR indicating that NZE women on average are

consuming iron intakes which are likely sufficient to meet their nutrient requirements. Nevertheless, it is well known that premenopausal women in New Zealand consume low dietary iron (University of Otago and Ministry of Health, 2011, Gibson *et al.*, 2002). It is therefore likely that there may be a few women who in fact do have excellent iron intakes and this may be giving a false impression of the actual iron intakes of the other NZE women. This is indicated by the large proportion (91.7%) of women who fall under the RDI value. It is also shown by the RDI cut-off point where 67% of women were found to have iron intakes below 77% of the iron RDI. In addition, the 6% of women who did not meet the EAR reference value are not consuming sufficient dietary iron, showing that a total of 82% of women have inadequate iron intakes. This indicates over three quarters of the NZE women are consuming inadequate dietary iron.

Premenopausal women need higher amounts of dietary iron due to menstruation, growth in adolescence and during pregnancy (National Health Medical Research Council, 2005). Fergusson *et al* (2001) found seven to 13% of New Zealand women aged 15 to 49 years to be iron depleted. This indicates therefore that many women in this study may in fact be iron depleted and at a high risk of iron deficiency anaemia. This is concerning given the essential role of iron in several metabolic functions and the adverse effects associated with low iron status such as impaired cognitive and immune function, decreased work performance, low energy levels, and poor pregnancy related outcomes (Brownlie *et al.*, 2004, Murray-Kolb, 2011, Scholl, 2005, Allen, 2000). Given the low iron intakes among these women interventions to increase dietary iron consumption and to increase iron absorption enhancers such as ascorbic acid should be implemented to increase iron status in premenopausal women (Heath *et al.*, 2001).

Vitamin D

The average intake of vitamin D in this study was 4.6 µg per day, and it was found that 64% of women consumed below the adequate daily intake for vitamin D. Vitamin D's primary role in the body is to assist with calcium absorption thereby maintaining bone health (National Health Medical Research Council, 2005). Vitamin D is obtained through both dietary sources and cutaneous synthesis from sunlight, making its status in individuals difficult to measure (National Health Medical Research Council, 2005). Given the current food supply, sufficient vitamin D status is nearly impossible to obtain through diet alone (Fuller, 2001). Calvo *et al* (2005) concluded that without fortification of foods dietary intake of vitamin D is insufficient to obtain adequate vitamin D status. Rockell (2006) conducted a study investigating vitamin D status in New Zealanders over 15 years of age and found the mean serum 25-hydroxyvitamin D

concentrations in New Zealanders to be 50 nmol/L indicating poor vitamin D status. Only 3% of individuals were found to be vitamin D deficient (≤17.5 nmol/L), however insufficient vitamin D levels were found in 84% of participants (≤80 nmol/L) (Rockell, 2006). Although dietary vitamin D consumption was not determined, these results indicate that dietary vitamin D was inadequate to maintain adequate vitamin D status. New Zealanders tend to consume low levels of foods rich in vitamin D such as fatty fish and organ meats and this is reflected in 55% of the women consuming inadequate vitamin D. The low intakes observed in this study are concerning as the adequate intake value is estimated to be adequate for a group of healthy individuals (Gibson, 2005). Intakes below this level therefore suggest inadequate intakes, especially during the winter months in New Zealand as UV exposure is poor due to less time spent outside and people tend to wear more clothing (Rockell, 2006).

Poor vitamin D intakes can be supplemented with adequate sun exposure throughout the summer months in New Zealand. Sunlight exposure is crucial to obtaining adequate vitamin D status for good health, and seasonal changes, especially in New Zealand have a significant impact on the cutaneous synthesis of vitamin D through the skin (National Health Medical Research Council, 2005, Rockell, 2006). It is likely that seasonality plays a large role in vitamin D synthesis among New Zealanders with large differences seen in serum vitamin D (Rockell, 2006). Concentrations were found to be lowest during spring and the highest during the summer months with the estimated vitamin D synthesis during the winter months in Christchurch to be only 60 IU per day (Rockell, 2006). This indicates that dietary vitamin D intake is essential during the months with minimal UV light exposure. Similarly, Pasco (2001) also confirmed that during the winter months dietary vitamin D influences vitamin D status. As blood samples were not analysed as part of this study we speculate that the vitamin D status in these NZE women is poor, especially throughout the months with minimal UV exposure.

Obtaining adequate dietary vitamin D is also challenging due to no mandatory fortification of food vehicles in New Zealand. In America the fortification of milk and some breakfast cereals is mandatory, whereas in New Zealand fortification of food items is voluntary (Rockell, 2006, Calvo *et al.*, 2005, Calvo and Whiting, 2003). The American population have a higher vitamin D status compared to those in New Zealand which is likely due to their mandatory fortification policies (Calvo *et al.*, 2005). As few foods are rich sources of vitamin D, consideration of ways to improve vitamin D consumption are warranted. Mandatory fortification of food vehicles such as margarine and milk may help NZE women obtain sufficient dietary vitamin D intakes, especially throughout the winter months.

Calcium

On average, the NZE women were meeting the EAR for calcium, however 17% still had intakes below the EAR, and 38% were not meeting the RDI. Low calcium intakes are common throughout dietary assessment with the 2008/09 National Nutrition Survey showing that 71.2% of NZE women in the NZ population were consuming inadequate calcium intakes (University of Otago and Ministry of Health, 2011). Calcium is stored in teeth and bone and is essential to maintain structure and strength of the skeleton (National Health Medical Research Council, 2005, Flynn, 2003). Calcium in addition to vitamin D therefore also plays a critical role in bone health as shown by Ransdale *et al* (1994) who found a significant inverse relationship between dietary calcium and bone density independent of body mass. The proportion of women consuming less than 77% of the RDI was 11.5% and this is concerning because combined with the 17% below the EAR means that 28.5% of NZE women have insufficient calcium intakes. Adequate calcium consumption is essential, especially during young adulthood to attain peak bone mass, and also during adulthood to slow the decline of bone density (University of Otago and Ministry of Health, 2011). The low calcium intakes seen in New Zealand also extend to other countries such as America. Fleming (1994) showed that a large proportion of individuals do not meet the RDA and that women between 12 and 29 years consume less than 60% of the recommended daily calcium intake. It is essential that premenopausal women attain adequate calcium intake to decrease the risk of fractures and osteoporosis during later adulthood (Flynn, 2003). Strategies therefore should be implemented to improve the calcium status of NZE women.

Folate

Dietary folate intakes were low with 25% of NZE women not meeting the EAR and 46.3% of women not meeting the RDI. This is reflected in the 2008/09 National Nutrition Survey, where 4% of premenopausal women had red cell folate levels indicating a high risk of a neural tube defect (NTD) pregnancy, and only 27% of women had levels indicating a low risk (University of Otago and Ministry of Health, 2011). Folate is vital for healthy cell growth and development and is an essential nutrient in pregnancy to prevent neural tube defects (National Health Medical Research Council, 2005). In 2003, the prevalence of NTD rates was the highest in early pregnancy terminations in New Zealand (5.7 cases per 10,000 births), followed by live births (3.4 per 10,000) (Ministry of Health, 2015a). This prevalence has increased since 1999 where NTDs accounted for five per 10,000 births (live births and stillbirths) (Ministry of Health, 2003). Lewis *et al* (1999) estimated that 68-87% of women premenopausal women had inadequate serum folate levels and a review of folate intakes in Europe also showed that only a small

proportion of women meet the recommended dietary intake of folate per day (>350 µg/d) (De Bree *et al.*, 1997). This aligns with the intakes in this study where a quarter of the women are not consuming adequate folate intakes. Further, the proportion of women consuming below 77% of the RDI is 23%. This indicates that 48% of women are consuming inadequate folate intakes. As these women are of child-bearing age this is concerning as folate is essential for proper brain function, aids in the production of DNA and RNA, especially during periods of rapid growth such as during pregnancy, therefore deficiencies may give rise to neural tube defects (Mrc Vitamin Study Research, 1991, Smithells *et al.*, 1976, Wagner, 1996). Public health strategies to increase the folate intakes of these women should be considered such as the mandatory fortification of folic acid in bread and baked items.

Currently folic acid fortification of bread is voluntary in New Zealand. USA, Chile, Canada and Australia all have mandatory folic acid fortification of flour (Ministry of Health, 2015a). This fortification has been proven to be effective in Canada, reducing the rate of NTDs by 46% (De Wals *et al.*, 2007) and in 2012 Australian women of all ages were consuming folate intakes above the EAR (Australian Bureau of Statistics, 2014). Although many bread companies in New Zealand currently fortify their products with folic acid, mandatory fortification may be beneficial in increasing folate status in NZE women. Nevertheless, as this strategy has already been considered in New Zealand, alternative interventions should be developed.

Dietary fibre

Dietary fibre intakes for the majority of the NZE women were adequate (30 g/d), however 28% were still consuming less than the adequate intake (AI) per day (25 g/d). This contradicts the findings in the 2008/09 National Nutrition Survey which found that women were consuming on average 18 g of fibre per day (University of Otago and Ministry of Health, 2011). The women in this study therefore may have much higher fibre intakes compared to the rest of the New Zealand population. One reason for this may be the type of women this study attracted. Some of the women were interested in health and were part of sports teams therefore they may have already been eating a balanced healthy diet, including foods from the four main food groups. Alternatively, given that 28% of women had intakes below the AI, it is likely that there are a few women who have excellent dietary fibre intakes and that their intakes are skewing the rest of the data. Inadequate dietary fibre intakes have also been shown in the United States of America (USA) where on average less than half the recommended intakes (15 g) are consumed (Slavin, 2005, Howarth *et al.*, 2001). This has also been seen in the United Kingdom (UK) where the average dietary fibre intake is 20 g per day. (Bingham, 1979). Additionally, the women in this study may also have over-reported their intakes of high fibre foods in the

NZWFFQ. Nevertheless, the proportion of individuals who have low fibre intakes is concerning as inadequate fibre intake has been clearly linked with body weight regulation and bowel health (Burton-Freeman, 2000, Howarth *et al.*, 2001, Marlett *et al.*, 2002). A study by Du *et al* (2010) found an inverse relationship between dietary fibre intake and BMI and waist circumference as did Murakami *et al* (2007) who showed an independent negative association between body weight and dietary fibre intakes. Interventions to increase the dietary fibre intakes of NZE women should be implemented and targeted at those who currently do not meet the recommended guidelines.

5.2.2 BCP groups

There were notable differences in the nutrient intakes between some of the BCP groups; however these were not significantly different. Presented below are findings from the HH, NN and NL BCP groups which had the highest and lowest intakes of the nutrients.

HH group

The HH group had the largest intake of energy (9296.2 ± 2505.5 kJ/d), total fat (89.4 ± 31.5 g/d), saturated fat (36.5 ± 15.4 g/d), monounsaturated fat (30.4 ± 10.8 g/d), and sodium (2661.9 ± 1028.1 mg/d). The high energy intake may be due to the accompanying high fat consumption in this group of women. Fat is energy-dense providing 37.7 kJ/g compared to that of carbohydrate which provides 16.7 kJ/g, therefore providing more energy in smaller amounts of food (National Health Medical Research Council, 2005). Fat is also highly palatable and therefore may lead to overconsumption and increase body fatness (Bray *et al.*, 2004). This is evident in these women who had both a total fat and saturated fat intake above that of the NN BCP group. Studies have shown that energy-dense food items high in fat tend to be less satiating leading to weight gain and subsequently overweight body compositions (Blundell and Macdiarmid, 1997). Tremblay (1989) found that a diet high in fat leads to increased adiposity which is likely due to the hyperphagic effects of a high fat intake. This suggests that individuals in the HH BCP group may not only consume more energy-dense foods than the other BCP groups, but they may also consume them in larger portion sizes leading to their high BMI's and BF%. Interestingly, the energy intake of the HH BCP group (9296.2 ± 2505.5 kJ/d) was similar to that of the NN BCP group (9198.3 ± 2141 kJ/d). This may be due to the HH BCP group underreporting their intake. Murakami and Livingstone (2015) showed overweight and obese individuals to be associated with under reporting of energy intakes which may explain the similarities seen between the HH and NN BCP group energy intakes.

The HH BCP group also had the highest sodium intakes. Although the NN (2457.5 ± 713.3 mg/d) and NH (2468.6 ± 771.6 mg/d) BCP groups also consumed sodium intakes above the recommended upper limit of 2300 mg per day, the HH BCP group had the highest intakes consuming 2661.9 mg per day (table 4.5). The high sodium intakes in these women are similar to the results of from Ministry of Primary Industries investigation (Skeaff, 2013). They found that almost 93% of adults had urinary sodium excretion values indicating sodium intakes above the suggested dietary target (SDT) of 1600 mg per day for sodium (Skeaff, 2013). Additionally, they found 76% of individuals had sodium excretion values indicating sodium intakes above the recommended upper level of 2300 mg per day (Skeaff, 2013). Energy dense food items high in both fat and salt lead to over consumption and increased adiposity (Birch, 1999). The positive relationship that can be seen between these two nutrients can have a profound effect on health outcomes such as a high salt intake leading to hypertension which when coupled with a high fat intake and high BF% is a major risk factor for coronary heart disease and stroke (Nishida *et al.*, 2004). The high sodium intakes in the HH BCP group indicates this group may not only consume foods that are high in fat and saturated fat, but also those which are associated with a high salt content such as bread, breakfast cereals, cheese, processed meats, sauces and spreads (Heart Foundation, 2013).

The HH BCP group also had the lowest intakes of vitamin C (131.6 mg), folate (408.9 µg) and calcium (1159.5 mg) compared to the other BCP groups, although this difference was not significant. Interestingly, these mean values also met the EAR and RDI recommendations for each nutrient indicating sufficient intakes. This is similar to Chai (2010) who found no significant differences in the dietary intakes of lipid-soluble micronutrients between different BMI's. Kimmons (2006) also did not see any differences in the vitamin C intakes between individuals of different BMI's which is similar to the results from this study. Although the calcium intake (1159 mg) of these individuals met the RDI (1000 mg), the intake was still lower than the other BCP groups. Literature agrees with this finding with studies showing low calcium intakes to be associated with a higher BF% (Zemel, 2000). Tidwell and Valliant (2011) also showed that individuals with lower calcium and vitamin D intakes had higher levels of adiposity. The lower intakes of nutrients in the HH BCP group indicates that these women's diets are not as nutrient dense as women in other BCP groups, and strategies to increase the nutrient density of their diets would be beneficial.

NN group

The NN group had the lowest protein (93.4 g), B12 (4.5 µg), iron (11.9 mg) and zinc (11.7 mg) consumption per day, however had the highest carbohydrate (242.2 g), and sugar (130.2 g)

intakes. Despite having the lowest protein, B12 and zinc intakes these values are still above the EAR and therefore are not a concern. Iron intakes in this group; although above the EAR, are still significantly lower than the RDI. Given the proportion of women in the total cohort who are consuming insufficient iron intakes it is likely that this also extends to this group of women (Looker *et al.*, 1997). The low intakes of nutrients seen in these women are all associated with animal protein. Red meat is a great source of protein, B12, iron and zinc (Williams, 2007). It is therefore possible that these women consume red meat less frequently than women of other BCP groups and therefore the low levels of these nutrients are seen. Schulze (2006) and Maskarinec *et al* (2000) both found an inverse relationship between a dietary pattern consisting of a high intake of red meat and weight gain among women which further confirms this association.

The higher carbohydrate intakes seen in the NN BCP group indicate that individuals who have a lower BMI and BF% tend to consume a greater proportion of carbohydrate. This is reflected in the body compositions associated with each of the BCP groups. The median BMI in the NN group was 21.4 kg/m^2 and BF% 25.8% compared to 28.6 kg/m^2 and 39.1%, respectively in the HH BCP group. Similar findings have also been demonstrated in the literature. Miller *et al* (1990) found obese individuals to consume 46% of energy intake from carbohydrate whereas lean individuals consumed 53% of total energy as carbohydrate. Merchant *et al* (2009) also found that consuming a diet with less than 47% of total energy from carbohydrate was associated with an increased risk of being overweight or obese among healthy adults. Similarly, Bowman's (2002) results also support the higher consumption of carbohydrate in individuals with lower BF%'s.

These findings of higher carbohydrate consumption among women with a NN body composition indicate that these individuals consume less meat and high fat items but more fruit, breads and whole grains. These food items are more energy restrictive and nutrient dense which likely contribute to these women's body composition (Bowman and Spence, 2002). Literature also reflects this trend and shows that individuals who follow a 'healthy' dietary pattern consume a diet with a higher percentage of total energy from carbohydrate and are more likely to have lower BF%'s (Newby *et al.*, 2003). Controversy however is present in the literature, where Chai (2010) showed that individuals with higher carbohydrate and fat intakes are more likely to be overweight or obese. This may be due to the type of carbohydrates consumed, where items that are both high in refined carbohydrate and fat tend to be nutrient poor and energy-dense leading to passive overconsumption and subsequent weight gain (Drewnowski, 2007).

Although the intakes in this group are referred to as the highest intake, they are in no way excessive and are no cause for concern as discussed in the following section on macronutrient distribution. Overall, these women consume a nutrient dense diet but still follow the trend of inadequate iron intakes.

NL group

The NL group had the highest PUFA (13.5 g), dietary fibre (32.9 g), folate (467.4 µg), calcium (1409.4 mg), iron (13.1 mg), zinc (12.8 mg), and selenium (102.0 mg) intakes per day. These findings indicate that the NL group have a nutrient dense diet and this is reflected in their body composition of a normal BMI with a low BF%. It is likely that these individuals consume a low energy but nutrient dense diet. As far as we are aware, no other studies have been conducted looking at the dietary patterns of premenopausal women with normal BMI and low BF%, therefore no similarities to other studies can be drawn. Nevertheless, these individuals are still consuming iron intakes below the RDI continuing the trend of low iron consumption regardless of body composition.

5.2.3 Macronutrient distribution

The macronutrient distribution profile of the NZE women did not meet all of the AMDRs. The women on average consumed a low carbohydrate and high saturated fat diet with moderate protein intakes. This trend was consistent when comparing the sample population as a whole, within each BCP group and in each of the dietary patterns.

Protein

Dietary analysis revealed the NZE women in this study meet the AMDRs for protein, consuming on average 18% of total energy intake. The Ministry of Health's AMDRs advise an intake of 15 to 25% of energy from protein to maintain a balanced diet (National Health Medical Research Council, 2005). These results are similar to that found in the New Zealand National Nutrition Survey (Ministry of Health, 2014b) where the NZ population consumed 16.4% of total energy as protein.

Results between the BCP groups were also similar to the NZ population where all groups met the AMDR. There was however a significant difference between the protein consumption of the three main BCP groups (NN, NH, HH) where the NN group consumed the least amount of protein (17.3±2.7%) and the HH group the most (18.3±3.4%). Although the HN BCP group consumed 22.3% of energy from protein, however because there were only three participants in this group this is not a good representative of individuals with this body composition. The New Zealand National Nutrition Survey showed that the average protein intake was 73 g,

whereas the intakes of the BCP groups were all over 90 g of protein per day. This indicates that the women in this study consume larger amounts of protein compared to the New Zealand population.

Many studies have shown beneficial effects of increased percentage intake of protein relative to carbohydrate intakes for weight reduction (Layman, 2003, Noakes *et al.*, 2005, Skov, 1999). The protein intakes in this study were the highest among the HH BCP group and high BF% and these women also had high energy intakes. The high protein intakes may be associated with larger portion sizes and overall energy intakes (Kral and Rolls, 2004). The correlation may also be due to the type of protein consumed. Studies have found positive relationships between meat consumption and weight gain (Wang and Beydoun, 2009, Vergnaud *et al.*, 2010). This relationship is thought to be due to meat containing higher amounts of energy, total and saturated fat leading to weight gain (Vergnaud *et al.*, 2010). Conversely, the consumption of dairy products have been shown to be associated with weight regulation (Mirmiran *et al.*, 2004, Zemel, 2004). Zemel (2003) showed that increasing dietary calcium results in reduced adiposity in the absence of energy restriction in obese individuals. As the HH BCP group had the largest protein intakes and the highest BF%, it is likely that they consume more meat and less dairy products compared to the other BCP groups which contribute to their body composition.

Total fat

The NZE women consumed on average 34.8% (86.7 ± 28.0 g/d) of energy from total fat, meeting the AMDR of 25 to 35% of total energy intake. This is higher than the NZ population who consume 33.6% (69 g/d) of energy as total fat (University of Otago and Ministry of Health, 2011). This trend has also been seen in the United States where dietary fat provides 31.9% to 36.9% of total energy intake per day in adults (National Health and Medical Research Council III, 1988-1991). Intakes of total fat over the AMDR were found in 39% of women. These high total fat intakes were also present within some of the BCP groups where significant differences were found. The NN, NL and HN groups, although in the upper end of the recommendations, met the AMDR; however the NH and HH groups consumed above the AMDR with 35.5% (87.5 g) and 35.3% (89.4 g) of energy coming from total fat, respectively. This indicates that the higher the BF% the more total fat is consumed. Miller *et al* (1990) showed that obese individuals consumed 35% of energy from fat, compared to lean individuals who consumed only 29% from fat. The individuals in the HH BCP group consumed the least amount of carbohydrate and the same amount of protein compared to the other groups, indicating that they consumed the rest of their energy as fat. They also had the highest amount of total

energy consumption (9296.2 ± 25055 kJ/d) out of all the BCP groups which likely plays a role in their high BMI and BF%. Previous studies have found that women had a higher risk of obesity when a greater percentage of energy was obtained from fat, protein or animal protein indicating that excessive total fat intakes in the NZE women may contribute to excess adiposity and an adverse body composition (Murtaugh *et al.*, 2007). High fat intakes in these women are therefore likely to be contributing to their excess adiposity which may lead to adverse health outcomes such as cardiovascular disease, insulin resistance and type 2 diabetes (Nicklas, 2001).

Saturated fat

The total NZE women in this study did not meet the AMDR for saturated fat (<12% total energy intake), consuming on average 13.9 ± 3.9% of total energy intake. These findings align with those from the New Zealand National Nutrition Survey where the NZ population consumed 13% of total energy intake as saturated fat (University of Otago and Ministry of Health, 2011). Each of the BCP groups and all four dietary patterns also had saturated fat intakes above the AMDR indicating that no BCP group follows the AMDR guidelines. This is concerning as excess saturated fat intake has been associated with increased adiposity (Hariri *et al.*, 2010, Field *et al.*, 2007). Miller (1990) found that obese women derive a greater proportion of total energy intake from fat (36.3 ± 1.5%) compared to lean women (28.6 ± 1.5%). This has also been shown in a study by Alfieri (1997) who showed that overweight and obese individuals consume a diet significantly higher in dietary saturated fat compared to their lean counterparts. This has been reflected in the study participants where women in the HH BCP group had the highest saturated fat intakes compared to those who were in the HN BCP group who had the lowest intakes. The women in the NN and NH BCP groups also had saturated fat intakes above that of the recommended level indicating that their saturated fat intakes may result in progressive weight gain over subsequent years.

A further concern is the link between excess saturated fat intake and adverse health outcomes. It is well established that excess adiposity is associated with the development of chronic diseases such as CVD, type 2 diabetes, hypertension, insulin resistance, dyslipidaemia, osteoarthritis, sleep apnoea, metabolic syndrome, and some cancers (Kannel *et al.*, 1996, Nicklas, 2001, Oliveros, 2014, James *et al.*, 2004, Manson, 1990). These women were screened prior to recruitment for the presence of any chronic diseases, however on-going consumption of high saturated fat intakes may lead to an increased risk of these morbidities. Decreasing saturated fat intakes have been shown to improve health outcomes and decrease the risk of chronic disease (Hu, 2001).

Carbohydrate

On average the NZE women consumed 41.9% (233.9 ± 74.6 g/d) of total energy intake from carbohydrate (table 4.4) which is below the AMDR guidelines (45-65% of total energy intake) (National Health Medical Research Council, 2005). This intake is also below the mean carbohydrate intake for the NZ population who consume 47.1% (211 g/d) of energy intake as carbohydrate (University of Otago and Ministry of Health, 2011). These findings indicate that these women consume a higher proportion of protein and fat to make up their total energy intake each day. Further analysis revealed 64% of the NZE women were consuming less than the AMDR guidelines. Merchant *et al* (2009) suggested that consuming less than 47% of energy from carbohydrate is associated with an increased risk of obesity. This has also been shown by other studies where Lluch (2000) found carbohydrate intakes to be 44% of total energy intake and total fat intakes to be 37.5% of total energy intake showing that this pattern of macronutrient intake is common among overweight women. Nevertheless, the low carbohydrate intakes in these women also trended into the BCP groups where the NN group consumed significantly more carbohydrate (43.2 ± 6.6%) than the HH BCP groups (41.5 ± 7.7%). As these intakes are below 47% of total energy intake it may be that the women in the NN BCP group are at an increased risk of weight gain. Conversely, many studies show the role of a higher carbohydrate diet in weight gain moderation (Miller *et al.*, 1990, Bowman and Spence, 2002). Nevertheless, Miller *et al (1990)* and Bowman *et al* (2002) both referred to carbohydrate intakes of 53% and 55% of total energy intake, respectively to aid in weight management. These intakes are therefore higher than what the women in this study are consuming which further confirms that they may be at an increased risk of weight gain.

Several other factors may also explain the low carbohydrate intakes seen in these women. Firstly, a low carbohydrate diet may be eaten to compensate for the consumption of foods with undesirable nutrient profiles. For example, consuming fewer carbohydrates means this energy needs to be replaced with protein or fat to maintain satiety and body weight (Miller *et al.*, 1990). The dietary data suggest that these women compensate the low carbohydrate intakes for a higher consumption of fat, where excess total fat intakes were seen in 39% of the women and 66% were consuming over the recommendations for saturated fat.

Secondly, a low carbohydrate diet has been highly publicised as a healthy diet to maintain or lose weight. The presence of this pattern in the majority of the women is not surprising as dietary trends in the media currently promote the 'high fat low carbohydrate' and 'paleo' fad diets which typically consist of low carbohydrate and high protein and fat (Cordain *et al.*, 2005). Carbohydrates, especially sugar have been portrayed in the media to be detrimental to

health and the cause of major weight gain and the current obesity epidemic (Swinburn, 2004). Although this claim may be true for many energy-dense high added sugar foods such as cakes, biscuits, refined breads and SSBs; whole grain breads and cereals provide essential nutrients to a balanced diet (Gil *et al.*, 2011). Many individuals, especially women succumb to current trends in the media and thus this may be why the identified dietary patterns reflect this way of eating. Low carbohydrate intakes however have also been reported as having the potential to be detrimental to health when followed over several years (Bilsborough, 2003). Complications include health arrhythmias, cardiac contractile function impairment, osteoporosis, kidney damage, lipid abnormalities and increased cancer risk (Bilsborough, 2003). As the emergence of this dietary pattern is relatively new, further research is required to determine the safety and efficacy of following this pattern long term.

Thirdly, underreporting may play a role. Dietary reporting from the participants may not have been quantifiably precise. Retrospective dietary intake is often misreported as it is cognitively challenging for many participants to complete an extremely accurate FFQ (Thompson, 2008). An individual's perception of what they eat may be completely different to what they actually consume each day, therefore leading to discrepancies such as under reporting in the final data.

Finally, social desirability and social approval bias have the potential to severely skew participant reporting (Hebert, 1995, Gibson, 2005). Social desirability is the participant wanting to display an image keeping within the social norm, and social approval is where participants report their intake to avoid criticism and achieve what the researchers are looking for (Hebert, 1995, Gibson, 2005). Scagliusi *et al* (2003) found that women were more likely to report their energy intake in a socially desirable way and food items which are considered 'fattening' or 'unhealthy' such as lollies, fried foods and refined breads were more likely to be under reported. It is therefore possible that social desirability in regards to their carbohydrate intake beliefs may have played a role in their reporting.

5.3 Top 40 Food Items

The top 40 food items consumed by the NZE women were determined for the total population and the three main BCP groups (NN, NH, HH). These were determined using daily equivalent frequencies of consumption reported in the NZWFFQ. Mean daily weights and the number of participants consuming the items daily were also determined.

Whole population

The most frequently consumed foods for the total NZE women included a range of food and beverages outside of the four food groups such as water, oil, coffee, tea and butter. Fruit and vegetables comprised the majority of the other items, however foods from the breads and cereals and milk and milk product food groups were also present (e.g. milk, yoghurt, wholemeal bread, and crackers) (table 23). Interestingly given the adequate protein intakes of this group, the only item from the lean meat and legume food group was eggs with no animal protein in the top 40 food items, suggesting the reason for the increased frequency of consumption seen for fruit and vegetables per day. For example, most individuals would consume animal proteins once per day whereas for other items such as bread or water would be consumed several times per day (University of Otago and Ministry of Health, 2011).

Butter was the fifth most commonly consumed food in the NZE women which aligns with the National Nutrition Survey, where butter was the largest contributor to saturated fat intake (University of Otago and Ministry of Health, 2011). Wholemeal and multigrain breads were also commonly consumed by the NZE women aligning with the national nutrition survey where 65.9% of women ate a light or heavy grain bread (Ministry of Health, 2014b). In association with the macronutrient distributions, only four items from the breads and cereals food group were present in the top 40 items. This may contribute to the low carbohydrate intakes seen within this population as both the portion size and the number of people consuming these daily, were small. Although apples, bananas and oranges were also present in the top 40 foods these were also consumed in small quantities with a mean 84.7g per day of apple consumed equalling approximately one small apple. In countries around the world such as the USA, few individuals have been shown to meet the fruit and vegetable guidelines (Kimmons *et al.*, 2009, Casagrande *et al.*, 2007). Further discrepancies have been seen in the literature between the recommended daily intake of actual fruit consumption by individuals. Gonelevu *et al* (1997) found that both normal and overweight women did not meet the recommended five plus servings per day of fruit and vegetables and on average reached three and a half serves. In New Zealand, 65.8% and 72.7% of women ate the recommended fruit and vegetable intakes per day, indicating that over a quarter of women still have inadequate intakes (University of Otago and Ministry of Health, 2011).

Discretionary items which were commonly consumed include lollies, chocolate bars and diet soft drink. This is similar to those identified by Quatromani *et al* (2002) who found a dietary pattern characterised by high intakes of lollies, and high fat foods, and low intakes of fruits, vegetables and lean meats. A similar pattern was also identified by McNaughton *et al* (2008)

which was characterised by sweet and savoury snack foods, potato chips, confectionary, cakes, soft drinks, and flavoured milks.

BCP groups

The dietary trends present in the total NZE women were also evident within the BCP groups. Water and oil used for cooking were ranked the top two items most commonly consumed in all BCP groups. The HH group consumed water and oil for cooking more frequently than the other groups, although they were both ranked first and second, respectively in the BCP groups. They also used oil as a dressing more frequently than the other groups with this making the third top food in the HH group, compared to the eighth and ninth food item in the NN and NH groups, respectively. Oil is very energy dense, therefore it can significantly increase the caloric content of a meal (Bes-Rastrollo, 2008). This result shows that women with a high BMI consume oil more frequently compared to those with a normal BMI, therefore it is possible that the habitual intake of oil contributes to their excess body fat. Available evidence however indicates that olive oil does not contribute to weight gain. Bes-Rastrollo *et al* (2008) and (2006) found that high fat items such as oil and nuts were not associated with weight gain. Benitez-Arciniega *et al* (2012) also showed that oil consumption was not associated with BMI when adjusted for energy intake. Other factors such as the consumption of other discretionary foods may therefore contribute to a high BMI and BF% body composition.

Fruit and vegetables were commonly consumed by all BCP groups; however the NN and HH group had the highest rankings, mean daily intakes and the most individuals consuming them each day for the majority of the foods. The most commonly eaten fruits were apples and bananas. This is similar to Russell's (1999) findings who identified bananas to be the most commonly consumed fruit by New Zealanders followed by apples, oranges and stone fruit when in season. The most commonly consumed vegetables were lettuce, carrot, onion and broccoli. This is also similar to Russell's (1999) findings that carrots, tomatoes, lettuce, onions and peas were the most commonly consumed vegetables by New Zealanders per week. Seasonality differences are unlikely to explain the variances seen in consumption because participants were recruited throughout all four seasons; therefore seasonality differences were accounted for. Increasing fruit and vegetable intake may reduce the risk of overweight and obesity (He *et al.*, 2004). The comparable consumption of fruit and vegetables seen in the HH BCP group to those in the NN BCP group therefore indicates that the HH BCP group may consume other items which are energy-dense that may contribute to their increased adiposity.

The highest ranking item from the breads and cereals food group was multigrain bread, which was ranked as one of the top 10 food items consumed by all three BCP groups. This supports data indicating that in New Zealand, bread is the main contributor to carbohydrate intakes (Russell, 1999). Bread is a household staple in New Zealand and therefore is likely to contribute to the carbohydrate intakes of these women (Ni Mhurchu and Ogra, 2007).

Discretionary foods such as chocolate bars and diet soft drink were ranked the highest in the HH BCP group. These individuals consumed the largest amounts and had the most people consuming these items each day(Swinburn, 2004). Literature clearly identifies the link between SSB consumption and weight gain (Nicklas, 2001, Nikpartow *et al.*, 2012, Schulze, 2004, DiMeglio, 2000, Johnson *et al.*, 2009). A causal relationship has also been shown between diet soft drinks and a high BMI (Liebman *et al.*, 2006). Liebman *et al* (2006) found that individuals who consumed diet soft drinks were more likely to also consume fast-food and larger portion sizes and also engage in less physical activity to help facilitate a healthy body weight. As the HH BCP group were the only group to have diet soft drinks identified in their top 40 food items consumed, it is likely that these play a role in increasing energy and fat intakes thus contributing to their body composition.

Overall, the consumption of the core staples in the New Zealand diet such as bread, tea, coffee and butter were common among all of the BCP groups. The higher consumption of oil, diet soft drink and the lower consumption of fruit and vegetables may distinguish individuals in the HH BCP groups from those with lower levels of adiposity.

5.4 Dietary Patterns

Dietary patterns were identified to investigate how dietary intake affects body composition profiles. Using factor analysis, four dietary patterns were derived: 1. 'Snacking' pattern, 2. 'Energy-dense meat' pattern, 3. 'Fruit and vegetable' pattern, 4. 'Healthy' pattern. Participants were categorised into tertiles according to their dietary pattern scores. Participants in the top tertile had a diet considered to be following this pattern. Individuals with low scores on this pattern (tertile 1) were considered to be loosely associated with the pattern and not following it directly.

Dietary pattern characteristics

The four dietary patterns identified are distinctly different from each other and three of the four are similar to those found in previous studies. The 'snacking' pattern (pattern 1) is similar to the 'junk food' pattern identified by Kourlaba *et al* (2009) and the 'snacky' pattern identified by Aranceta *et al* (2003). The pattern in this study is characterised by cheese, crackers, peanut

butter, cakes, biscuits, and sweet and savoury snack foods. It is not associated with green vegetables, red meat or eggs. The other patterns identified are similar to those outlined by other studies. The 'energy-dense meat' pattern (pattern 2) is similar to the 'Western' pattern identified by Schulze (2006) or the 'empty calorie' pattern identified by Quatromani *et al* (2002). Participants following this pattern frequently consume potatoes, white and discretionary breads, all types of meat, puddings and crumbed and fried foods. They do not consume high calcium milk, yoghurt, soy products or water. The 'fruit and vegetable' pattern (pattern 3) is similar to the 'healthy' pattern identified by Suliga (2015) or Newby *et al* (2006), however both of these patterns included other items such as dairy and fruit juice, whereas the pattern in this study only loaded on fruit and vegetables. This pattern was not associated with the consumption of coffee. The 'healthy' pattern (pattern 4) was similar to the 'bean' pattern identified by Maskarinec *et al* (2000). Those following the pattern consume whole grains, fish and seafood, legumes, soy products, nuts, seeds and coconut fats. They do not consume brown breads or sweetened cereals.

Age, BMI and BF%

The 'snacking' pattern had a significant difference in the age of the NZE women between tertiles 1 and 3. Women who followed this pattern (tertile 3) were older (33.9 ± 7.9 years) compared to those who followed it less closely (tertile 1) (31.9 ± 8.7 years) (table 4.11). Women following this pattern, although not significant had a higher BMI (25.9 ± 6.5 kg/m^2) and BF% (33.7 ± 8.5%). This suggests that women who are older snack more often than younger women and this may lead to a high BMI, high BF% body composition. Conversely, Basdevant *et al* (1993) found those who snacked throughout the day were younger (40 ± 13 years) compared to those who did not snack (43 ± 12 years), however they also found a positive correlation between BMI and snacking. When age, BMI and BF% were broken down into their groups, the majority of women of all ages, BMI's and BF%'s loaded in tertile 3 (table 4.12). This indicates that all NZE women consume equal amount of the foods associated with the 'snacking' pattern. In agreement with this is Piernas and Popkin (2010) who found that women from 19 to 39 years derive a larger amount of energy from snacks which was also associated with increased energy intake compared to those older or younger. This age range contains the majority of the NZE women, therefore suggests that snacking is prevalent at any age and may significantly contribute to women's energy intakes eventually leading to an increased BMI.

The 'energy-dense meat' pattern also had a significant difference in both age and BMI across all tertiles (table 4.12). This pattern had a positive association with BMI and an inverse

association with age, where younger women aged 15 to 24 years, followed this pattern more closely compared to those who were older (36 to 45 years). It also suggests that those who follow this pattern tend to be overweight compared to those who only consume a few foods associated with this pattern. No other dietary patterns showed a significant relationship between age, BMI or BF% which is consistent with other studies where no significant differences between BMI and dietary patterns at baseline were present (Newby *et al.*, 2003). Adolescents have been shown to have an increased consumption of soft drinks and fast-food, both of which similar to this dietary pattern (St-Onge *et al.*, 2003). The similar 'western' pattern has been associated with an increase in weight gain and a higher risk of being overweight as the loadings in the pattern increased (Schulze, 2006, Quatromani *et al.*, 2002). This indicates that if the young women (15 to 24 years) in our study continue to follow this pattern into adulthood, they have an increased risk of becoming overweight or obese. Interventions can be developed and targeted at these young women to improve their nutrition and decrease their risk of excess adiposity.

The lack of significant association between the other dietary patterns and age, BMI and BF% indicates that the women eat a varied diet and do not solely follow one dietary pattern. Body composition may therefore have stronger associations with other factors such as portion sizes, physical activity and food availability rather than the overall specific dietary pattern. Much literature has been reported on the relationship between portion size and increased adiposity. Rolls *et al* (2002) found larger portion sizes regardless of individual characteristics and serving methods to lead to increased energy intake. Additionally, Kral and Rolls (2004) and Berg *et al* (2009) also found increased portion sizes to contribute to weight gain.

In the 'fruit and vegetable' and the 'healthy' patterns participant reporting accuracy and social desirability bias may have influenced the lack of significant associations seen between age, BMI, BF% (table 4.11, 4.12). Reporting dietary intake retrospectively is difficult and may lead to inaccuracies between actual and reported intakes and therefore is not quantifiably precise (Thompson, 2008). When completing the NZWFFQ they may have reported what they think they should be eating, how they would like to eat, or what they think the researcher wants to see, which would contribute to the lack of association between the dietary patterns and BCP groups (Hebert *et al.*, 1997). These biases in the reported dietary data may contribute to biased results and therefore significant associations were not seen.

Micronutrient intakes

All micronutrient intakes were significantly different between the dietary patterns (tertile 3) apart from vitamin B6 and alcohol. These differences demonstrate that each of the dietary patterns has different nutrient profiles, and that individuals following each of the patterns will also have different levels of nutrient intake and adequacy.

Women following the 'snacking' pattern had moderate intakes of all nutrients compared to the other dietary patterns (table 4.13). Many food items in this pattern are nutrient poor and energy-dense, nevertheless, the more nutritious items associated with this pattern such as high calcium milk, cheese, and brown bread provide valuable nutrition to the dietary pattern to such a degree that dietary recommendations are met.

Individuals following the 'energy-dense meat' pattern are most likely to have the highest energy, protein, total and saturated fat, sugar, carbohydrate, vitamin B12, iron, calcium and zinc intakes (table 4.13). Food groups that loaded on this pattern include high fat cheese, and red, white and processed meats which are likely to contribute to the high protein and saturated fat content as well as the vitamin B12, iron and zinc intakes. It also includes white and discretionary breads, sauces, creamy dressings, crumbed and deep fried foods, sweet snack foods and fruit drinks which all contribute to the high energy, total and saturated fat and carbohydrate intakes (Swinburn, 2004). As the energy intake of this pattern is significantly larger than the other dietary patterns, it is reasonable to assume that this pattern contributes higher amounts of many other micronutrients. Having the highest energy and saturated fat intakes, it can be suggested that individuals from the HH BCP group follow this pattern most closely as they have been found to also consume a high energy and high fat diet. Kong *et al* (Kong *et al.*, 2009) found a diet high in fat and carbohydrate to lead to weight gain. Although the HH BCP group had lower carbohydrate intakes, these women may consume more meat, creamy dressings and fried foods contributing to higher fat consumption. This is also supported by Murtaugh *et al* (2007) who found that individuals consuming a diet higher in saturated fat were associated with a higher risk of obesity.

Individuals who consumed few foods from the 'energy-dense meat' pattern (tertile one) had the lowest intakes of protein, polyunsaturated fatty acids, vitamin B12, iron and zinc. As this pattern is the only one which contains meat it is logical that this pattern contains both the highest and lowest protein, iron and zinc intakes depending on the extent to which the pattern is followed. Although this pattern does have some benefits such as the high calcium, zinc and B12 intakes, it also has some aspects such as the high saturated fat and sugar content which

are detrimental to health and can lead to increased adiposity (Swinburn, 2004). This pattern is similar to the 'empty calorie' diet identified by Quatromani *et al* (2002) which was also regarded as an energy-dense diet and associated with a 40% increase risk of being overweight when following this pattern. Individuals who loaded highly in the 'energy-dense meat' pattern in this study had a mean BMI of 26.4 ± 6.7 kg/m^2 and a BF% of 34.3 ± 9.2% indicating that women following this pattern were also overweight and had a high BF%. This further confirms the patterns association with these women. Interventions targeting this dietary pattern may be beneficial to improve the weight regulation and health of these women.

The 'fruit and vegetable' pattern had the highest intakes of vitamin A, C and dietary fibre (table 4.13). This pattern may be associated with the HN BCP group who also had the highest intakes of these nutrients. Women who were in tertile 1 of this pattern had the lowest intakes of fibre, vitamin C and vitamin A. Fruit and vegetables are valuable sources of these nutrients therefore individuals consuming few foods from this pattern are likely to find it challenging to obtain sufficient amounts of these nutrients (Van Duyn and Pivonka, 2000). It is likely that women in the NH or HH BCP groups do not follow this pattern. The NH BCP group had the lowest fibre and vitamin A intakes which is also shown by Garcia (2012) who found an inverse relationship between measures of obesity and vitamin A intakes. Additionally, the HH BCP group had the lowest vitamin C intakes which also correlated with previous research showing an inverse relationship between BMI, BF% and vitamin C intakes (Johnston *et al.*, 2007). This finding contradicts that of the top 40 food items where fruit and vegetable intakes in the HH BCP group were shown to be comparable to that of the NN BCP group. The differences seen may be due to smaller quantities of these foods being consumed by individuals in the HH BCP group. Although the overall energy intake of these individuals is high, it is likely that they consume energy-dense, nutrient-poor food items which contribute to their low levels of micronutrient intakes (Garcia, 2012). This is confirmed through their relationship with the 'energy-dense meat' pattern.

The women following the 'healthy' pattern had the highest vitamin D intakes, lowest calcium intakes and moderate intakes of all other nutrients (table 4.12). This dietary pattern loaded highly on fish and seafood as well as egg and egg dishes, which are all good vitamin D sources (Chen *et al.*, 2007). Nevertheless, this pattern contains no dairy products contributing to the lowest calcium intakes of all the identified dietary patterns. The nutrient characteristics of this pattern align with the HH, NH and NL BCP groups; therefore one group cannot be linked to this pattern. Women in New Zealand and around the world on average have low vitamin D and calcium intakes as mentioned previously and this is therefore concerning for bone health in

later life (Rockell, 2006, Fleming, 1994, Ramsdale *et al.*, 1994, University of Otago and Ministry of Health, 2011).

The 'energy-dense meat' pattern can be clearly associated with the HHBCP group while looser correlations can be made between the other patterns. It is likely that women of all ages and body compositions consume foods from the 'snacking' pattern, whereas younger overweight women were more likely to consume foods from the 'energy-dense meat' pattern and not from the 'fruit and vegetable' pattern. Given the clear relationship between younger overweight individuals with the 'energy-dense meat' pattern, dietary interventions can be developed to target women with a high BF% in an attempt to reduce body weight and improve their health outcomes.

Macronutrient intakes

Protein

The AMDR (15-25% of total energy) for protein was met within each of the dietary patterns Table 4.14). The 'healthy' pattern had the highest percentage of energy from protein (19.2 ± 3.9%) compared to the other dietary patterns, and significant differences were also seen between the pattern tertiles. The 'healthy' pattern is associated with high protein items such as fish and seafood, legumes, eggs and soy products. This is similar to the 'bean' pattern identified by Maskarinec (2000) which has been classed as a health conscious pattern due to the inverse relationship with BMI. Increases in protein intake, especially meat alternatives have been associated with increased satiety and weight regulation (Layman, 2003, Noakes *et al.*, 2005, Te Morenga and Mann, 2012). This suggests that individuals following this pattern consume less animal products and also have a normal BMI. Women in tertile three of this pattern have a normal BMI (24.8 kg/m^2) indicating that women in the NL BCP group may be associated with this pattern as they also had the highest protein intakes.

The 'energy-dense meat' pattern also had significantly different protein intakes between the tertiles. This pattern was associated with red, white and processed meat consumption. Increased red meat consumption has been associated with increased BMI due to its high energy and saturated fat content (Wang and Beydoun, 2009, Vergnaud *et al.*, 2010).

These results show that higher protein intakes from meat alternatives may attenuate weight gain and lead to a healthy body weight. The NL BCP group may follow the 'healthy' pattern as associations can be made due to their normal BMI and low BF%, showing this pattern may aid in body weight regulation.

Total and saturated fat

Total fat intakes varied between the dietary patterns. The 'snacking' and 'fruit and vegetable' patterns both met the AMDR but the 'energy-dense meat' and the 'healthy' pattern both had excessive intakes (35.9 ± 6.3% and 36.7 ± 7.9%, respectively).

Individuals following the 'fruit and vegetable' pattern had total fat intakes within the AMDR, however those who consumed only few items from this pattern had intakes exceeding the recommendations (36.8 ± 6.5%). Fruit and vegetables were the only food items which loaded highly on the pattern thus indicating that individuals who follow this pattern also consume other foods which are higher in saturated fat. Confirming this is Schulze (2006) who found individuals following a 'western' dietary pattern characterised by low intakes of fruit, vegetables and whole grains was associated with a diet of higher energy and total fat intake.

The 'energy-dense meat' pattern also had a total fat intake above the AMDR in tertile three however the difference between the tertiles was not significant. Nevertheless, individuals who loaded in tertile three of this pattern had significantly higher saturated fat intakes compared to those in tertile one. Overweight and obese individuals are more likely to consume a greater amount of saturated fat compared to those of normal weight, therefore this further confirms the association between the 'energy-dense meat' pattern and the HH BCP group (Alfieri, 1997).This is likely due to the high animal protein consumption associated with this pattern (Wang and Beydoun, 2009, Vergnaud *et al.*, 2010). Additionally, the high saturated fat items such as snack foods, fried foods, and high fat cheese associated with this pattern are likely contribute to the increased adiposity seen among these women (Swinburn, 2004).

Carbohydrate

Significant differences in carbohydrate intakes were identified between each of the tertiles in the 'healthy' pattern. Individuals who loaded in tertile one of the 'healthy' pattern had the highest carbohydrate intakes (43.2% ± 5.8). Studies have shown that whole grain consumption may contribute to a healthy body weight (Good *et al.*, 2008). It could be speculated that the NN group consume only few foods from this pattern as this group had the highest carbohydrate intakes. Decreasing the amount of energy from fat and increasing the consumption of complex carbohydrate has been shown to have a beneficial effect on body weight and body fatness (Saris *et al.*, 2000, Poppitt *et al.*, 2002). Bowman and Spence (2002) showed that adults eating greater than 55% of energy from carbohydrate were more likely to have a BMI below 25 kg/m^2. Shay *et al* (2012) showed that a diet higher in complex carbohydrates and lower in saturated fat and protein is associated with lower energy intakes, a

more favourable micronutrient profile and a lower BMI. This further confirms the loose association of the NN BCP group with the 'healthy' pattern. Although carbohydrate intakes for this pattern are still well below this threshold, it indicates that the higher carbohydrate intakes of the NN BCP group may be dictating their body composition through decreasing the overall consumption of total fat and energy.

5.5 Diet Quality

Women in the HH BCP group did not consume significantly different nutrient intakes compared to other groups. They met all of the EAR's except for iron and vitamin D; however this was consistent within all BCP groups. Individuals who are overweight or obese consume adequate energy intakes. Once the EAR's are met through the consumption of nutrient dense foods, the discretionary foods consumed provide excess energy which will contribute to weight gain (Garcia, 2012). Women who have poor micronutrient status may therefore make poor food choices and / or have alterations in micronutrient metabolism (Kimmons, 2006). Women with higher BF%'s may metabolise specific micronutrients via different pathways and therefore may have higher micronutrient requirements compared to those with lower adiposity (Chai, 2010).

Vitamin A

Women in the HH BCP group had vitamin A intakes which met both the EAR and RDI and were not significantly different to the other BCP groups (table 4.5) (National Health Medical Research Council, 2005). Previous studies have shown the inverse association between BMI and carotenoids to be independent from dietary intake (Chai, 2010). As the vitamin A intakes in these women appear to be sufficient from a dietary intake perspective, further research is warranted to investigate the nutritional status of these ladies from a biological perspective.

Vitamin D

Individuals with a HH body composition had one of the highest vitamin D intakes, although this still did not meet the adequate level of 5 µg per day (table 4.5) (National Health Medical Research Council, 2005). This was consistent however throughout the whole study population. Not only is vitamin D obtained through dietary means, but sunlight in the New Zealand summer months is also a main source (Rockell, 2006, National Health Medical Research Council, 2005). Vitamin D status has been strongly associated with different levels of adiposity and it was found that vitamin D concentrations in obese New Zealanders were 6 nmol/L lower than that of individuals who were of normal weight (Rockell, 2006, Cheng *et al.*, 2010). Previous studies have reported the fat soluble vitamin D to be sequestered and stored in fat cells in those with high BF%'s leading to a lower vitamin D status compared to individuals with

less body fat (Cheng *et al.*, 2010, Martini and Wood, 2006). These results suggest that another mechanism may be present as individuals of a HH body composition had vitamin D levels comparable to the rest of the NZE women. Additionally, other factors may also influence their status such as sunlight exposure, where individuals with a leaner body composition may participate in a higher amount of physical activity outdoors and therefore a greater absorption of vitamin D through the skin (Cheng *et al.*, 2010).

Iron

Women in the HH BCP group had the highest intakes of iron; however, they still did not meet the RDI (table 4.5). This BCP group was most associated with the 'energy-dense meat' pattern which contained red, white and processed meat. No other dietary pattern contained animal protein, thus explaining the highest iron intakes in this pattern. New Zealand women and those with a high BF% have routinely been shown to have low iron levels, with studies showing a higher prevalence of iron deficiency in overweight and obese women compared to their normal weight counterparts (Cepeda-Lopez *et al.*, 2011, Yanoff *et al.*, 2007). As the HH BCP group in this study consumed the highest iron intakes, it is likely that iron is metabolised by a different mechanism compared to those with a lower BF% (Cepeda-Lopez *et al.*, 2011, Yanoff *et al.*, 2007, Zimmermann *et al.*, 2008).

Vitamin E

Women in the HH BCP group had the same vitamin E intakes as the NN and NH BCP groups (table 4.5). Literature reports conflicting views on vitamin E metabolism and its status in individuals with a high BF% (Mehmetoglu *et al.*, 2011, García *et al.*, 2009). These data suggest there are no significant differences in vitamin E intakes between individuals of different body compositions, therefore different mechanisms for metabolism may be present in those with a higher BF%.

Zinc

Women in the HH BCP group had zinc intakes comparable to that of the other BCP groups. Previous research has shown those who are overweight or obese have high dietary zinc intakes, but the same zinc status as individuals with lower adiposity (Ennes Dourado Ferro, 2011). This indicates that those with excess adiposity may require a higher zinc intake compared to those with a lower BF%.

Vitamin C

Women in the HH BCP group had the lowest vitamin C intakes compared to the other groups (table 4.5). Lower dietary intakes may be responsible for the lower levels of vitamin C routinely

seen in this population with higher body fat. Garcia (2012) found a negative relationship between vitamin C status and BMI. Similar results were also seen by Johnston *et al* (2007) where vitamin C was negatively associated with BMI, BF% and waist circumference. As previously mentioned, the HH BCP group was largely associated with the 'energy-dense meat' pattern. This pattern does not load on any fruit or vegetables which are high in vitamin C and this may be a cause of the low intakes observed (Garcia, 2012). Although it does not rule out any differences in vitamin C metabolism between those of different body compositions, it does suggest that differences in food choices lead to different intakes of vitamin C and this may be a contributor to the low levels observed in these individuals. Increased vitamin C intakes in individuals with a HH body composition may be beneficial to increase their serum levels.

These results show that the intakes of micronutrients in overweight and obese individuals are not significantly different to that of normal weight women; yet previous research indicates that the concentrations seen in these women are low. Further research is warranted into the mechanisms behind the lower concentrations of these micronutrients and whether higher nutrient intakes would be beneficial for women with a higher BF%.

Chapter 6 Conclusions

6.1 Aim of the research

Body composition determines an individual's risk of many chronic diseases. Specifically, excess body fatness has been associated with a number of adverse health outcomes including hypertension, dyslipidaemia, insulin resistance, type 2 diabetes and cardiovascular disease (University of Otago and Ministry of Health, 2011, World Health Organisation, 2015, Stein, 2004, Oliveros, 2014, Poirier *et al.*, 2006, Pi-Sunyer, 2002). Body mass index is a commonly used measure to identify an individual with excess body fat (Flegal *et al.*, 2009). Many individuals however are misclassified using this measure and therefore those with excess body fat may not be identified as having increased health risks (Oliveros, 2014, Gallagher *et al.*, 2000). Habitual dietary intake is a factor which determines body composition and thus identifying eating patterns that are predictive of excess body fat in women may be of value in assessing chronic disease risk (Swinburn, 2004).

Few studies have investigated how the current dietary intakes and eating patterns of women relate to BF%, BMI and the tailoring of dietary advice according to these body fat profiles. The aim of this study therefore was to identify eating patterns of premenopausal NZE women participating in the wider women's EXPLORE study. The objectives of this sub-study were to explore the dietary intakes of the NZE women in different BCP groups, to identify eating patterns which are the strongest predictors of body fatness, and to explore the differences in the macronutrient distribution profiles and diet quality between the BCP groups and the identified eating patterns. Investigating these factors will contribute to our understanding of particular dietary intakes and eating patterns associated with different BCP groups. This will enable us to identify targeted interventions to help improve health outcomes in women with excess body fat.

This study was a sub-study of the wider cross-sectional comparative designed 'Examining Predictors Linking Obesity Related Elements' (EXPLORE) study in young adult women. The study took place at Massey University Albany Campus, North Shore Auckland. It investigated the dietary data obtained from a validated 220-item, self-administrated, semi-quantitative FFQ which was completed by 231 post-menarche, pre-menopausal NZE women. Height and weight were taken and BF% was measured using air displacement plethysmography (BodPod). Participants were categorised into one of three body composition profile (BCP) groups: normal BMI (18.5-24.9 kg/m^2), normal BF% (≥22%, <30%) (NN); normal BMI, high BF% (≥30%) (NH); high BMI (≥25 kg/m^2), high BF% (HH). Dietary intake, macronutrient profiles and diet quality,

along with dietary patterns identified using principal component factor analysis, were analysed for the total NZE population and BCP groups. Associations between dietary patterns and age, BMI and BF% were also investigated.

6.2 Main findings and Conclusions

The main findings and final conclusions of this study will be presented according to the research objectives as they were stated in chapter 1.

- The first objective was: *"to explore the dietary intakes of women in the different body composition profile (BCP) groups".*

The dietary intakes in the NZE women between each of the BCP groups were explored and clear differences micronutrient intakes have been found. A concerning number of NZE premenopausal women consumed inadequate intakes of iron (82%), vitamin D (55%), folate (48%), calcium (28%) and dietary fibre (28%) putting them at risk of nutrient deficiencies. Nevertheless, all nutrient intakes on average apart from iron and vitamin D within the BCP groups were adequate to meet the nutrient reference values.

The HH group had the largest intakes of energy (9296.2 kJ/d), total fat (89.4 g/d), saturated fat (36.5 g/d), monounsaturated fat (30.4 g/d), and sodium (2661.9 mg/d). This group also had the lowest intakes of vitamin C (131.6 mg), folate (408.9 µg) and calcium (1159.5 mg) compared to the other BCP groups. These results indicate that these women may not consume as nutrient dense diets compared to women in the other BCP groups, and that their food choices may be significantly different to that of women with lower BF%'s. Strategies to reduce the energy and fat consumption in these women would be beneficial to aid in weight management.

The NN group had the lowest protein (93.4 g), B12 (4.5 µg), iron (11.9 mg) and zinc (11.7 mg) intakes per day. These nutrients are clustered in animal protein-rich foods; therefore it is likely that these women consume less red meat compared to other BCP groups. Overall, these women consume a nutrient dense diet but still follow the trend of inadequate iron and vitamin D intakes.

The NL group had the highest PUFA (13.5 g), dietary fibre (32.9 g), folate (467.4 µg), calcium (1409.4 mg), iron (13.1 mg), zinc (12.8 mg), and selenium (102.0 mg) intakes per day indicating that these women consume a nutrient dense diet which is reflected in their body composition of a normal BMI with a low BF%.

Common household staple items were identified as the most frequently consumed food items by the NZE women such as water, oil, coffee, tea and butter. Fruit and vegetables, bread, milk and yoghurt were also present. The HH group consumed diet soft drinks more frequently than the other groups which have been shown to increase the consumption of other food items high in energy and fat, such as chocolate bars. The HH group also consumed oil for cooking and chocolate bars more frequently than the other groups; likely increasing their energy intake and contributing to their excess adiposity.

- The second objective was: *"to identify the eating patterns which are the strongest predictors of increased body fat".*

The patterns which are the strongest predictors of body fat have been explored and four dietary patterns were identified: The 'snacking' pattern, 'energy-dense meat' pattern, 'fruit and vegetable' pattern, and the 'healthy' pattern.

The 'snacking' pattern was associated with women of all ages, BMI and BF%'s. This indicates that all women may consume food items from the 'snacking' pattern, such as peanut butter, sweet spreads, cakes, biscuits and sweet and savoury snack foods, regardless of their body composition. These women however are less likely to eat vegetables, red meat and egg and egg dishes.

The 'energy-dense meat' pattern was associated with younger (16-24 years) and overweight (26.4 kg/m^2) women suggesting that this pattern leads to increased body fatness. This pattern was associated with the consumption of red, white, and processed meats, pudding, and crumbed and deep fried foods, but with a lower intake of high calcium milk, yoghurt, soy products and water. As a result, individuals following this pattern are also most likely to have the highest energy, protein, total and saturated fat, vitamin B12, iron, calcium and zinc intakes. Foods consumed from this pattern in conjunction with those from the 'snacking' pattern are likely to contribute to excess adiposity seen in the HH BCP group. Development of dietary strategies in the community targeting this specific dietary pattern will be beneficial to improve the health of individuals following this pattern.

The 'fruit and vegetable' pattern was associated with the HN BCP group as they had the highest vitamin A and C intakes showing that they consume plenty of fruits and vegetables but are less likely to consume coffee. This pattern was not however, associated with the NH BCP group as they had the lowest intakes of vitamin A and fibre, or the HH BCP group as they had

the lowest vitamin C levels. This indicates that women with a high BF% may have low fruit and vegetable intakes which likely contribute to their body composition.

Women following the 'healthy' pattern are likely to have the highest, although still insufficient, vitamin D intake, the highest protein intake, and the lowest calcium intake. These nutrients are obtained through whole grains, fish and seafood, legumes, nuts and seeds, but not white and brown breads, sweetened cereals or fruit juice. This pattern was linked to women in the NL BCP group who also had the highest protein intakes.

- The third objective was: *"to explore the differences in the macronutrient profile intakes in women of different body compositions"*

The differences in macronutrient intake between the BCP groups have been explored. NZE women of all body compositions following any dietary pattern consume protein intakes meeting the AMDR guidelines.

On average the NZE women met the total fat AMDR guideline but did not meet the guideline for saturated fat. A large proportion of NZE women (39%) consumed over the AMDR for total fat, as did the NH and HH BCP groups (35.5% and 35.3%, respectively). Additionally, a large proportion of NZE women (66%) and all of the BCP groups also consumed over the AMDR for saturated fat. High total fat intakes were also seen in the 'energy-dense meat' pattern and individuals who scored high on this pattern had significantly higher saturated fat intakes compared to those who were not. The saturated fat intake (13.1%) of women following the 'fruit and vegetable' pattern also exceeded the guidelines, indicating that women who follow this pattern may consume foods outside of this pattern that are high in saturated fat.

The average carbohydrate intake for the total population was low (41.9% of total energy intake), where 64% of the NZE women had intakes below the AMDR. The women associated with each of the BCP groups as well as the four dietary patterns also had carbohydrate intakes below the AMDR. The HH BCP group consumed significantly less carbohydrate (41.5%) compared to the NN BCP group who had the highest intakes (43.2%). As the HH BCP group exceeded the AMDR guidelines for both total fat and saturated fat, the high fat intakes seen in these women are therefore likely to be contributing to their excess adiposity, which may lead to adverse health outcomes. Individuals in the NH BCP group also consumed less carbohydrate and more total and saturated fat compared to the NN BCP group. This indicates that a higher carbohydrate and lower fat intake may be associated with a lower BMI and BF% body composition.

- The final objective was: *"to explore the micronutrient intake in each BCP group and compare the differences in diet quality".*

The micronutrient intakes of each BCP group were investigated in regards to diet quality. Women in the HH BCP group had vitamin A, E, and zinc intakes comparable to the other BCP groups. They also had one of the highest vitamin D and iron intakes, although not meeting the AI and RDI, respectively. The Iron and vitamin D intakes therefore indicate inadequate intakes among all NZE women and that the lower micronutrient concentrations seen in individuals with a high BF% may be independent of dietary intake, while biomarkers were not measured. Further research is therefore indicated into the metabolism of fat soluble nutrients, and whether they are sequestered in body fat leading to lower circulating plasma levels in women with a high BF%.

6.3 Study strengths

This study has several strengths which contribute to the final outcomes. They include the method of body composition analysis, using a validated FFQ, analysing seasonal eating patterns, and using dietary pattern analysis.

Body composition analysis

Using air displacement plethysmography (ADP) to determine body composition is a strength of this study. This method is emerging as the 'gold standard' of body composition analysis (Fields *et al.*, 2002, Collins and McCarthy, 2003). It provides a safe, fast and effective way to measure an individual's body composition accurately with minimal participant burden (Fields *et al.*, 2002, Lowry and Tomiyama, 2015, Ginde *et al.*, 2005, Collins and McCarthy, 2003). This highly accurate and precise assessment of body fat and lean mass was used together with dietary data to identify specific dietary patterns of the NZE women (Lowry and Tomiyama, 2015). We can therefore be confident that the BF% of these women is accurate and precise.

Validated FFQ

The FFQ has been validated and identified as a valid tool to determine the relationship between dietary intake, socio-demographic factors, and nutrition-related risk factors within a population (Houston, 2014). The FFQ included New Zealand specific foods and portion sizes making it relevant to the NZE women in assessing their dietary intakes. Misreporting of dietary intake was also accounted for in the nutrient analysis by using the Goldberg equation. This method highlights those individuals who over- or under-reported their energy intake in relation to their energy requirements in the FFQ. Individuals identified as mis-reporters were

excluded from the nutrient analysis. The dietary data obtained from this study can therefore be considered a valid and reliable representation of the NZE women's dietary intakes and eating patterns.

Seasonal eating

Recruitment of participants in this study occurred from August 2013 to December 2014. This gave a variety of dietary intakes over a range of seasons and therefore reflects seasonal changes in nutrient intakes and eating patterns. This ensures the eating patterns identified are an average of the total NZE population throughout the year.

Dietary pattern analysis

Using pattern analysis to assess the dietary intakes of these women was a strength of the study. Assessing the collinearity of foods and nutrients can be effectively used to determine dietary patterns and thus habitual food intake (Sacks *et al.*, 1995). Patterns of food intake represent daily occurrences, where nutrients are consumed together rather than in isolation (Sacks *et al.*, 1995). These habitually consumed combinations of foods may determine body composition and subsequent health outcomes (McNaughton *et al.*, 2007). The dietary patterns identified in this study therefore can be used to predict relationships between dietary intake and health outcomes, allowing interventions specific to these individuals who follow the patterns to be created.

Factor analysis reliability

A way to determine the reliability of factor analysis is to calculate the Cronbach's α. Cronbach's α is a lower bound estimate of reliability and provides a measure of internal consistency (Tavakol, 2011). The reliability of factor analysis is closely related to its 'reproducibility', where the test is considered reliable if it is able to be reproduced (Margetts, 2004). Alpha is used to test if two items are correlated to one another; the higher the correlation, the higher the alpha value. Alpha values below 0.7 are considered a low reliability in the outcome (Tavakol, 2011). The Cronbach's α values in this study were low, however very close to 0.7 and this may be due to poor inter-relatedness between items or heterogeneous constructs (table 4.10). (Tavakol, 2011). Many dietary papers tend to use eigenvalues, scree plots and 'interpretability' to determine the reliability of their dietary patterns (Suliga, 2015, McNaughton *et al.*, 2007, Murtaugh *et al.*, 2007, Newby *et al.*, 2004). This study has considered all four approaches to determine reliability; therefore the dietary patterns identified were taken to be reliable estimates of dietary patterns followed by the NZE women.

6.4 Study limitations

There are a number of limitations associated with dietary pattern analysis which may have influenced the outcome of this study. These include the study population characteristics, social desirability bias, the physical activity level of the individuals, interpretability of the dietary patterns, and the lack of blood sample analysis.

Study population

A convenience sample of NZE women living in Auckland were recruited via email distribution, pamphlet advertisements and word of mouth. Women who responded were interested in health and wellbeing, therefore were motivated to participate in the study. Many of the participants were also a part of sports teams or attended the gym regularly therefore may not be representative of the general New Zealand population.

As previously mentioned, social desirability and social approval bias may influence the reporting of the NZE women. Reporting how they think they should be eating, how they would like to be eating or wanting to 'please the researcher' may bias the dietary data results. This is a factor that is present in all self-report dietary assessments. The extent to which it influences the dietary data results should be assessed and adjustments should be made accordingly (Hebert *et al.*, 1997). In an attempt to reduce this bias, the NZWFFQ has been validated and has been shown to give an accurate representation of an individual's eating habits in relation to a food diary over the last month of consumption (Houston, 2014). Additionally, as previously mentioned, participant perception of what they actually eat may provide a large bias in the results. Reporting accuracy for frequency of foods consumed may be inaccurate leading to biased results. Misreporting of energy intake was accounted for by using the Goldberg equation and individuals identified as under or over reporting their energy intakes were excluded from the nutrient analysis section of this study.

Physical activity level

A limitation the Goldberg equation is the estimation of individuals physical activity levels (PAL). The participant PAL was not known for each participant in this study. A general PAL level of 1.55 for a lightly active individual was used for all participants. This value was selected based on previous research showing that it is a conservative value (Black, 2000). If the average PAL level was higher than the 1.55 used then the proportion of under and over reporters would increase and decrease, respectively.

Principal components analysis method

A limitation of the principal component method stems from the subjective decision in determining the number of factors to extract (Newby *et al.*, 2004). Although, scree plots and eigenvalues, all provide some guidance in this decision, ultimately the final decision is open to interpretability by the researchers. The choice to include four factors in this study was based on all four elements above and was believed to be the best fit to represent the dietary patterns of the NZE women in this study.

Biomarkers of dietary intake

Blood samples were not analysed as part of this study. Although the dietary intake of individuals were determined, blood samples would have been valuable in identifying individuals of different BCP groups who were in fact deficient in certain nutrients.

6.5 Recommendations

- Dietary intakes of iron, vitamin D, folate and calcium are low in many NZE premenopausal women. Interventions and dietary advice should be given to increase the intakes of these micronutrients to prevent potential adverse health outcomes. For example, a blog could be designed outlining the importance of iron, vitamin D, folate and calcium in the daily diet. The blog could also include the current intake guidelines, food sources and recipes which provide high amounts of these nutrients. This blog could link to a free application for use during grocery shopping which provides the food sources for these nutrients and recipes from the blog.

- Women with a high BMI (≥25 kg/m^2) and a high BF% (≥30%) body composition tend to consume a diet high in energy, total and saturated fat. Interventions to decrease the energy and fat consumption in these individuals will be beneficial to aid in weight management. For example, a policy could be introduced to reduce the advertisements and marketing stands of discretionary food items such as chocolate within supermarkets. These could be replaced with healthier alternatives such as fruit and vegetable stands. This will target all women who snack regularly; encouraging healthier alternatives, and also those with a HH body composition who tend to consume a diet high in energy, total and saturated fat.

- On average the NZE women do not follow the AMDR guidelines, consuming low carbohydrate and high saturated fat intakes. A visual aid, similar to the 'healthy plate

model' could be created which outlines the current AMDR guidelines and shows how individuals can easily meet this.

- All NZE women were found to frequently consume foods from the 'snacking' pattern. This pattern had a high saturated fat intake and contained nutrient-poor, energy-dense food items.
    - Dietary guidelines could be created targeting women who follow the 'snacking' pattern.
    - Focus on promoting the reduced consumption of cakes and biscuits, sweet and savoury snack foods and spreads to reduce energy, total and saturated fat intake.
    - Provide the rationale for reducing the intake of these items and include exciting healthy alternatives both for everyday consumption and social occasions.

- Overweight younger (16-45 years) women are more likely to follow the 'energy-dense meat' pattern. Dietary advice should be targeted at these women to decrease their energy intake, total fat and saturated fat intakes as well as limiting their added sugar intakes to decrease excess body fat.
    - Create dietary guidelines targeting overweight women aged 16 to 24 years who follow the 'energy-dense meat' pattern.
    - Encourage decreased consumption of white discretionary breads, processed meat, creamy dressings, pudding and fried foods.
    - Include ways to increase complex carbohydrates into their diet to replace white discretionary breads to aid in weight management.

- Individuals with a high BMI (≥25 kg/m^2) and high BF% (≥30%) are likely to consume less fruit and vegetables compared to those with a NN body composition. Strategies to increase the consumption of these foods are warranted.
    - Create dietary guidelines for women with a high BMI and BF% who do not follow the 'fruit and vegetable' pattern.
    - Include information on the role of vitamin A, C and dietary fibre in the body which will provide rationale and motivation for increased consumption.
    - Emphasise the current Ministry of Health 'five plus a day' guidelines and provide clear pictures and examples of appropriate portion sizes.

- Include ways to limit total and saturated fat consumption given the high intakes seen in these women.

- Individuals with a normal BMI (18.5-24.9 kg/m^2) and low BF% (<22%) body composition are more likely to be following the 'healthy' pattern. This pattern was not associated with the consumption of dairy products and had the lowest calcium intake out of all the dietary patterns.
    - Create dietary guidelines for these women following the 'healthy' pattern.
    - Focus on including calcium rich foods in their diet such as dairy products, and other sources such as tofu and bones of tinned fish.

Recommendations for further research

- Given the high fat and low carbohydrate intakes in these NZE women, further investigation should be undertaken to determine their cholesterol status and cardiovascular disease risk.

- Additional factors such as physical activity levels, socioeconomic status and food availability should be investigated to determine their relationship with body composition in these women.

- The consumption of snack foods is prevalent among all NZE women; therefore further investigation into the reasons and implications behind this snacking behaviour in regards to body composition is warranted. The newly developed S-EAT snacking tool can be used which provides information on individual's dietary habits (Philipsen, 2015). This tool could be used in conjunction with information on portion sizes and the dietary patterns obtained from the NZWFFQ, to gain a better understanding of the snack food choices of women with different body compositions.

- The dietary intakes of individuals in the HH BCP group indicate that they are consuming nutrient intakes at the same levels as their NN and NH counterparts. Further research is warranted to assess the prevalence of nutrient deficiencies in these individuals, such as vitamins A, D, E and zinc, and to explore the metabolic pathways of these micronutrients in individuals with excess adiposity.

6.6 Conclusion

Four main dietary patterns were identified among pre-menopausal women: The 'snacking' pattern, the 'energy-dense meat' pattern, the 'fruit and vegetable' pattern and the 'healthy' pattern. All NZE women frequently consume snack foods; however younger overweight women tend to follow the 'energy-dense meat' pattern more closely than other women, leading to high energy, total and saturated fat intakes. Women with a high BMI and high BF% were not associated with the 'fruit and vegetable' pattern, and women with a normal BMI and low BF% may follow the 'healthy' pattern. Additionally, New Zealand European women typically follow a low carbohydrate, high saturated fat diet, while those in the NH and HH BCP groups also had high total fat intakes. These are inconsistent with the AMDR guidelines and may contribute to the development of different body compositions. This clearly illustrates the dietary patterns that contribute to excess adiposity and provides rationale for the development of interventions targeted at women following these patterns, to reduce body fatness.

Inadequate intakes of iron, vitamin D, calcium and folate were prevalent among the NZE women and these results confirm the need for public health interventions to promote the importance and increase the consumption of these essential nutrients. Finally, vitamin A, D, E and zinc intakes among individuals with excess body fat appear to be comparable to that of women with normal body fatness. Further research should be conducted to investigate metabolic differences that explain the consistently low serum levels seen among these women.

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Appendices

Appendix A. Pre-screening health and demographic questionnaire

Women's EXPLORE study

Personal Information, Health and Demographics Questionnaire

First name: _____

Family name: _____

Name you would like to be called by: _____

Medical Practitioner: _____

Address: _____

Phone:_____

What is your first language?

English ☐

Other ☐

If other, please state:_____

I would like to receive a brief report summarizing the main findings of the project:

Yes □ No □

I am willing to be contacted in future research projects within the Institute of Food, Nutrition and Human Health:

Yes □ No □

Health and Demographic information

Do you have children? Yes □ No □

- How many children do you have? _____
- When was your youngest child born? __ / __ / ____ (DD/MM/YYYY)

When did your last period start? (Day / month / year) _____

Are you pregnant? Yes □ No □

Do you have any surgical or cosmetic implants? Yes □ No □

Are you currently in paid employment? Yes □ No □

If yes,

Full time Yes □ No □

Part time Yes □ No □

If yes, specify hours per week:_____

Describe your job or paid employment or work:

TITLE / DESCRIBE	HOURS PER WEEK

Do you follow a specific diet for health reasons? Yes □ No □

Please explain

_____

_____

_____

Do you follow any diet for cultural or religious reasons? Yes □ No □

If yes, what type of diet do you follow?

_____

_____

_____

_____

Are you taking any form of medication, including traditional or homeopathic medicine and contraception?

Yes □ No □

Please specify the condition, the medication and the dosage in the table provided.

Condition	Medication	Dosage	Frequency

Are you taking any form of supplements, including tablets or drinks? Yes □ No □

If yes, what are the name, brand and dosage of the supplements you are taking? ____

(Will send details by email Yes □ No □)

Supplement	Brand	Dosage	Frequency

Do you smoke cigarettes? Yes □ No □

If yes, approximately how many cigarettes per day:_____

_____

Do you drink alcohol? Yes □ No □

If yes, approximately how many standard drinks per week:_____

_____ _____

[1 standard drink = a glass of wine (120ml), 1 bottle/can of beer, I tot of spirits (45mL)]

Do you have any allergies? Yes □ No □

*Please specify*_____

_____

Please tell us how you found out about the Women's EXPLORE study. Did you found out from:

- A friend?

    - If yes, what is him/her name?.....
      .....
      .....
- An email list?
    - If yes, what is the name of the email list?.....
      .....
      .....
- At an event?
    - If yes, which event?.....
      .....
      .....
- Flyer on noticeboard?
    - If yes, where was the noticeboard?
      .....
      ……
      …
- Other……
  ……..……
  ……
  ……

Appendix B. Standard operating procedures for the food frequency questionnaire

Questionnaire Procedure

1. The questionnaires will be completed online using the computers in building 27. The two computers must first be turned on using the power button on the hard drive. You must then log in using the Explore network account, so that the computer is ready for the participants;

   Username: **XXXXXXXXXX**

   Password: **XXXXXXXXXX**

2. Once logged in please ensure that there are three questionnaire links on the desktop i.e. Food Frequency Questionnaire, Eating Habits Questionnaire, and the Eating Behaviour Questionnaire. Open up each link, ensuring there is access. If there are any issues, please ask Zara, AJ, Sara, Kathryn Beck, or PC to help. If the issue cannot be resolved, there are hardcopies for each of the questionnaires which are kept in the pink Explore questionnaire folder which is will be beside the computers at the questionnaire station. However, the hardcopy version must be a last resort as this will have to be put into surveymonkey manually by an Explore staff member at a later date, which is time consuming.

3. The next component to check is the guidelines for the weighed food record. There is a pdf on the desktop beside the questionnaire links called 'Weighed Food Record Guidelines', open this up and make sure it plays as a video. Check the sound, if there is no sound you may have to set up the headphones from the pink Explore folder. These can be plugged into the computer hard drive in the hole marked with a headphone symbol, plug in, put the earphones in your ears and check the sound again. If there are any issues, please see one of the team members listed above. If you are going to use earphones for participants, please ensure there are small steriliser wipes at the computer station. The earphones must be cleaned by the staff member managing the questionnaire station with the wipes after each participant use. This is to maintain hygiene.

4. Participants will move to the questionnaire station after completing the BP station, this BP station is very quick (3-5minutes maximum) so ensure you are prepared by this stage. The participants are offered breakfast and a hot drink once BP has been recorded, if the participant declines please escort them straight to the questionnaire station. If the participant would like breakfast and/or a hot drink, please encourage them to consume this

at the computer stations where they will begin the questionnaires (as time may be short with multiple participants on the testing days). The questionnaire station is time consuming (25-40 minutes) so it is important to get this underway as soon as possible.

5. Once the participant is seated infront of the computer, inform them that there are three questionnaires to complete, and a video to watch afterwards.

6. The first questionnaire to complete is the Food Frequency Questionnaire; open the link for the participant. Then read the first page to the participant, taking your time through the question examples, asking at the end if they have any questions.

7. Click 'next' at the bottom of the page and this will take you to the first questionnaire question which asks for the participant ID number, please insert this full number yourself i.e. 250018 and click 'next' at the bottom of the page.

8. The questionnaire is now ready for the participant to begin. Let the participant know that you will be there to answer any questions they have whilst completing it. Leave the participant and sit at the big round table behind the computer station, so that you are close enough for any possible questions, but so that you still give the participant some privacy.

9. It is important that conversation is kept to a minimum whilst participants are completing the questionnaires, they need full focus.

10. If any questions arise during this time from the participant that you are unsure of, please ask one of the team members stated above. It is important that we obtain the most accurate information possible from the questionnaires.

11. If the links (questionnaires) stop working at any time, please see a team member stated above. You may need to provide a hardcopy for the participant to complete. If so, please ensure they complete this hardcopy version from the beginning, as their questionnaire data will not be saved unless they have 100% completed it.

12. Once the participant has completed the food frequency questionnaire, please open the 'Eating habits' questionnaire for them to complete next. Again, open up link and read

the initial statement(s) to the participant. Enter in their participant ID number at the top, and then remind the participant again that you are free to answer any questions they may have over this time.

13. If there are any complications/issues please contact one of the staff members stated, and provide a hardcopy version only as a last resort (to complete from question 1 to the end).

14. Once completed, open up the 'Dietary behaviours' questionnaire, entering in the participant ID again, with the instructions as above.

15. Upon completion of the third questionnaire, the participant must watch the food record video. Open this up for the participant, and provide cleaned earphones if required.

16. Once this is finished, close the video and escort the participant to the large round table for the take home package station. This package is already set up for the participant, you are required to take the participant through; the weighed food record diary, food record example booklet, allocate and record four days for them to complete this on, electronic scales are provided if required, and then through the dietary diversity questionnaire, before the participant is equipped with the accelerometer.

17. Firstly, show the participant the weighed food record diary and explain this must be completed over the next four days i.e. if today's date of testing is Thursday the 12th of September, then the participant will complete a weighed food diary the following four days: Friday 13th, Saturday 14th, Sunday 15th and Monday 16th from when they wake up in the morning until when they go to bed at night. They must record the time of each meal, and weigh all food items they eat providing as much detail as possible when recording foods. We need four consecutive days of recording, which include at least one weekend day. If they go out for a meal, get them to describe the food as best they can, using the palm size as a portion tool or plate/bowel size.

18. Provide the participant with the food record example booklet, explain they can refer the picture numbers i.e. spaghetti bolognaise picture b.3 in their food diary if this helps for meals out or those they could not weigh.

19. Next, record the four days and dates (as explained above) in the participant's food diary record booklet, there are four lines at the beginning of the booklet to record this. Also record this on the calendar in the Explore pink folder. Explain that there are contact details on the front of the food record dairy which the participants can use if any questions arise while they are weighing their food and recording it.

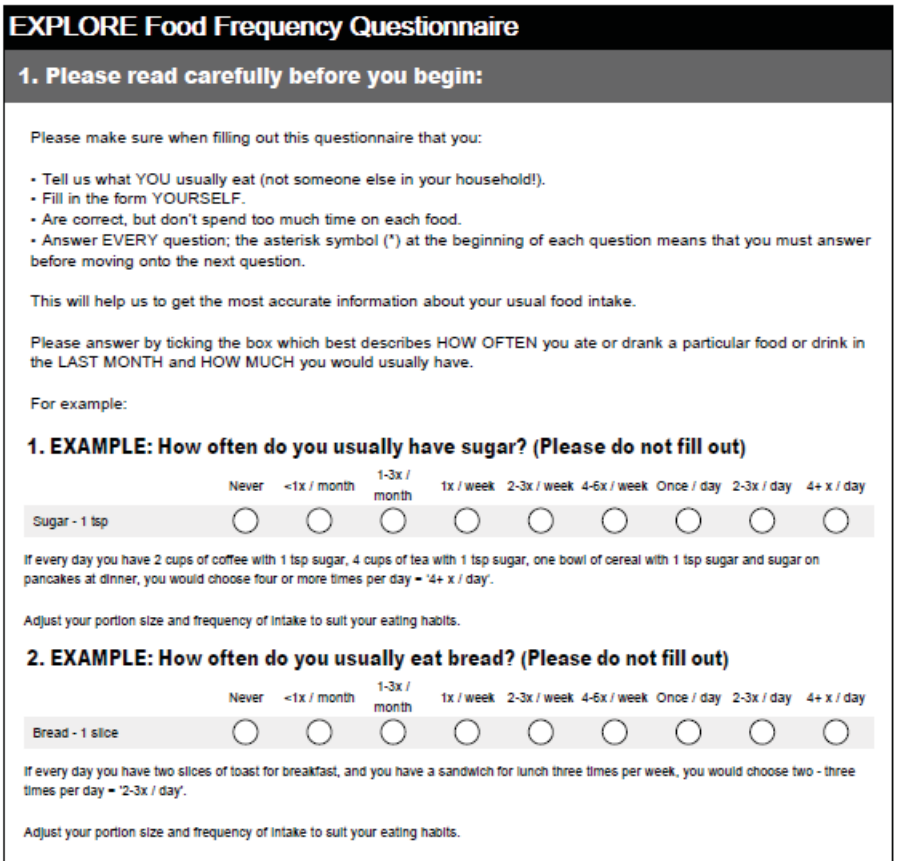
20. If the participant does not have a set of electronic scales at home, please provide them with some. If there are none in building 27, please see PC. Check that the scales have batteries in them, and that they work. Record the scale ID number on the back of the calendar with the participant name and date. The participant will be given a courier bag to return the scales in.

21. Finally, go through the Dietary Diversity Questionnaire with the participant. This is to be completed in 7 days' time when they take the accelerometer off. They only complete this questionnaire once, and emphasise how they must not look at their food record when completing this. The questionnaire is designed with a different purpose.

22. The weighed food record and the dietary diversity questionnaire need to be returned in the return envelope with the accelerometer after7 days. The courier bag with the scales can be sent back after the four days of recording.

23. Wendy will now complete the take home station setting the participant up with an accelerometer and petrol voucher.

Appendix C. Food frequency questionnaire



EXPLORE Food Frequency Questionnaire

1. Please read carefully before you begin:

Please make sure when filling out this questionnaire that you:

- Tell us what YOU usually eat (not someone else in your household!).
- Fill in the form YOURSELF.
- Are correct, but don't spend too much time on each food.
- Answer EVERY question; the asterisk symbol (*) at the beginning of each question means that you must answer before moving onto the next question.

This will help us to get the most accurate information about your usual food intake.

Please answer by ticking the box which best describes HOW OFTEN you ate or drank a particular food or drink in the LAST MONTH and HOW MUCH you would usually have.

For example:

1. EXAMPLE: How often do you usually have sugar? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sugar - 1 tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯

If every day you have 2 cups of coffee with 1 tsp sugar, 4 cups of tea with 1 tsp sugar, one bowl of cereal with 1 tsp sugar and sugar on pancakes at dinner, you would choose four or more times per day = '4+ x / day'.

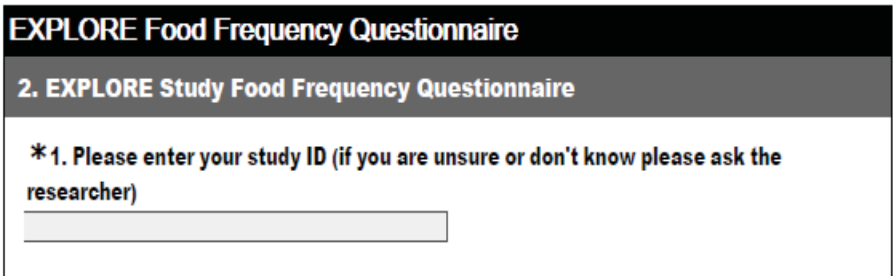
Adjust your portion size and frequency of intake to suit your eating habits.

2. EXAMPLE: How often do you usually eat bread? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

If every day you have two slices of toast for breakfast, and you have a sandwich for lunch three times per week, you would choose two - three times per day = '2-3x / day'.

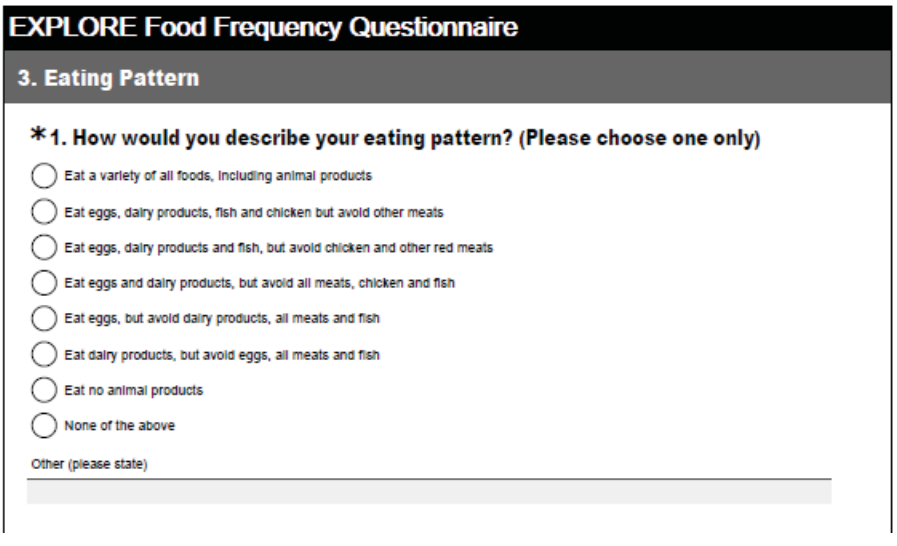
Adjust your portion size and frequency of intake to suit your eating habits.



EXPLORE Food Frequency Questionnaire

2. EXPLORE Study Food Frequency Questionnaire

***1. Please enter your study ID (if you are unsure or don't know please ask the researcher)**



EXPLORE Food Frequency Questionnaire

3. Eating Pattern

***1. How would you describe your eating pattern? (Please choose one only)**

- ◯ Eat a variety of all foods, including animal products
- ◯ Eat eggs, dairy products, fish and chicken but avoid other meats
- ◯ Eat eggs, dairy products and fish, but avoid chicken and other red meats
- ◯ Eat eggs and dairy products, but avoid all meats, chicken and fish
- ◯ Eat eggs, but avoid dairy products, all meats and fish
- ◯ Eat dairy products, but avoid eggs, all meats and fish
- ◯ Eat no animal products
- ◯ None of the above

Other (please state)

EXPLORE Food Frequency Questionnaire

4. Dairy

***1. Do you use milk? (e.g. fresh, UHT, powdered)**

- ◯ Yes
- ◯ No

2. What type(s) of milk do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Full cream milk (purple top)
- ☐ Standard milk (blue top)
- ☐ Skim milk (light blue top)
- ☐ Trim milk (green top)
- ☐ Super trim milk (light green top)
- ☐ Calcium enriched milk (yellow top) e.g. Xtra, Calci-Trim
- ☐ Calcium and vitamin enriched milk e.g. Mega, Anlene
- ☐ Calcium and protein enriched milk e.g. Sun Latte
- ☐ Standard soy milk (blue)
- ☐ Light soy milk (light blue)
- ☐ Calcium enriched soy milk (purple) e.g. Calci-Forte, Calci-Plus
- ☐ Calcium, vitamin and omega 3 enriched soy milk e.g. Essential
- ☐ Calcium and high fibre enriched soy milk e.g. Calci-Plus High Fibre
- ☐ Rice milk

Other (please state)

***3. On average, how many servings of milk do you have per day? (Please choose one only)**
(A 'serving' = 250 mL or 1 cup/glass)
e.g. 5 cups of coffee/tea using 50 mL of milk + ½ cup of milk on cereal = 1 ½ servings per day

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-2 servings
- ◯ 3-4 servings
- ◯ 5 or more servings

EXPLORE Food Frequency Questionnaire

*4. How often do you usually have milk?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Flavoured milk (milkshake, iced coffee, Primo, Nesquik) - 250 mL/ 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Milk as a drink - 250 mL / 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Milk on breakfast cereals or porridge - 125 mL/ 1/2 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Milk added to water-based hot drinks (coffee, tea) - 50 mL / 1/5 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Milk-based hot drinks (Latte, Milo) - 250 mL / 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

*5. How often do you usually eat cheese?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day	4+ x / day
Cheddar (tasty, mild, colby) - 2 heaped Tbsp / matchbox cube	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Edam, Gouda, Swiss - 2 heaped Tbsp / matchbox cube	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Feta, Mozarella, Camembert - 1 heaped Tbsp / 1 med wedge	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Brie, blue and other specialty cheese - 1 heaped Tbsp / 1 med wedge	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Processed cheese slices - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cream cheese - 2 heaped Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cottage or ricotta cheese - 2 heaped Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

*6. How often do you usually eat these dairy based foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Ice cream - 2 scoops	◯	◯	◯	◯	◯	◯	◯	◯	◯
Custard or dairy food - 1 pottle / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Yoghurt, plain or flavour - 1 pottle / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Milk puddings (semolina, instant) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fermented or evaporated milk (buttermilk) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

5. Bread

***1. Do you eat bread?**

- ◯ No
- ◯ Yes

2. What type(s) of bread, rolls or toast do you eat most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ White
- ☐ White – high fibre
- ☐ Wholemeal or wheat meal
- ☐ Wholegrain

Other (please state)

***3. What type of bread slice do you usually have? (Please choose one only)**

- ◯ Not applicable
- ◯ Sandwich slice
- ◯ Toast slice
- ◯ Mixture of both sandwich and toast slices

***4. On average, how many servings of bread do eat per day? (Please choose one only)**
(A 'serving' = 1 slice of bread or 1 small roll)

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1–2 servings
- ◯ 3–4 servings
- ◯ 5–6 servings
- ◯ 7 or more servings

EXPLORE Food Frequency Questionnaire

***5. How often do you usually eat these bread based foods?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Plain white bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
High fibre white bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Wholemeal or wheat meal - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Wholegrain bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fruit bread or fruit bun - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Wrap - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Focaccia, bagel, pita, panini or other speciality breads - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Paraoa Parai (fry bread) - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Rewena bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Doughboys or Maori bread - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

***6. How often do you usually eat these other bread based foods?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Crumpet or muffin split - 1 crumpet / 1 whole muffin split	◯	◯	◯	◯	◯	◯	◯	◯	◯
Scone - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran muffin or savoury muffin - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Croissant - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Waffle, pancakes or pikelets - 1 medium / 2 small	◯	◯	◯	◯	◯	◯	◯	◯	◯
Iced buns - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Crackers (cream crackers, cruskits, corn / rice crackers, vitawheat) - 2 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯

***7. Do you have butter, margarine or spreads on bread or crackers?**

◯ No

◯ Yes

EXPLORE Food Frequency Questionnaire

8. What type(s) do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

☐ Not applicable

☐ Butter (all varieties)

☐ Monounsaturated fat margarine e.g. Olive, Rice Bran, Canola Oil Spreads

☐ Polyunsaturated fat margarine e.g. Sunflower Oil Spreads

☐ Light monounsaturated fat margarine e.g. Olivio Spread Light

☐ Light polyunsaturated fat margarine e.g. Flora Spread Light

☐ Plant sterol enriched margarine e.g. Pro Active, Logical Spreads

☐ Light plant sterol enriched margarine e.g. Pro Active Spread Light

☐ Butter and margarine blend e.g. Country Soft, Butter Lea

Other (please state)

_____

***9. On average, how many servings of butter, margarine or spreads do you have per day? (Please choose one only)**
(A 'serving' = 1 level teaspoon or 5 mL)
e.g. 1 sandwich with butter thinly spread on two pieces of bread = 2 servings

◯ Not applicable

◯ Less than 1 serving

◯ 1–2 servings

◯ 3–4 servings

◯ 5–6 servings

◯ 7 or more servings

EXPLORE Food Frequency Questionnaire

6. Breakfast Cereals and Porridge

***1. Do you usually eat breakfast cereal and/or porridge?**

- ◯ No
- ◯ Yes

2. What breakfast cereal(s) do you eat most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Weetbix
- ☐ Refined cereals e.g. Cornflakes or Rice Bubbles
- ☐ Bran based cereals including fruity varieties e.g. Special K, Muesli, All Bran
- ☐ Sweetened e.g. Nutrigrain, Cocoa Pops
- ☐ Porridge

Other (please state) _____

***3. On average, how many servings of breakfast cereal or porridge do you have per week? (Please choose one only)**
(A 'serving' = ½ cup porridge, muesli, cornflakes or 2 weetbix)
e.g. ½ cup of porridge 3 times per week + 2 weetbix 4 times a week = 7 servings per week

- ◯ Not applicable
- ◯ Less than 4 servings
- ◯ 4–6 servings
- ◯ 7–9 servings
- ◯ 10–12 servings
- ◯ 13–15 servings
- ◯ 16 or more servings

EXPLORE Food Frequency Questionnaire

***4. How often do you usually eat porridge or these cereal foods?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Porridge, rolled oats, oat bran, oat meal - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Muesli (all varieties) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Weetbix (all varieties) - 2 weetbix	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cornflakes or rice bubbles - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran cereals (All Bran, Bran Flakes) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran based cereals (Sultana Bran, Sultana Bran Extra) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Light and fruity cereals (Special K, Light and Tasty) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chocolate based cereals (Milo cereal, Coco Pops) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sweetened cereals (Nutrigrain, Fruit Loops, Honey Puffs, Frosties) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Breakfast drinks (Up and Go) - Small carton / 250 mL	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

7. Starchy Foods

***1. Do you eat any type of starchy foods such as rice, pasta, noodles and couscous?**

- ◯ No
- ◯ Yes

***2. On average, how many servings of starchy foods such as rice, pasta, noodles and couscous do you eat per week? (Please choose one only)**
(A 'serving' = 1 cup cooked rice / pasta)
e.g. 1 cup of rice + ½ cup of pasta included in a lasagne pasta dish + 1 cup of spaghetti = 2.5 servings

- ◯ Not applicable
- ◯ Less than 4 servings
- ◯ 4–6 servings
- ◯ 7–9 servings
- ◯ 10–12 servings
- ◯ 13–15 servings
- ◯ 16 or more servings

***3. How often do you usually eat these starchy foods?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Rice, white - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Rice, brown or wild - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pasta, white or wholegrain (spaghetti, vermicelli) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned spaghetti (Watties) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Instant noodles (2 minute noodles) - 1 packet	◯	◯	◯	◯	◯	◯	◯	◯	◯
Egg and rice noodles (hokkien noodles, udon) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other grain (quinoa, couscous, bulgar wheat) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

8. Meat

***1. Do you eat beef, mutton, hogget, lamb, or pork**

- ◯ No
- ◯ Yes

***2. Do you trim any excess fat (fat you can see) off these meats? (Please choose one only)**

- ◯ Not applicable
- ◯ Always
- ◯ Often
- ◯ Occasionally
- ◯ Never cut the fat off meat

***3. On average, how many servings of meat e.g. beef, mutton, hogget, lamb or pork do you eat per week? (Please choose one only)**
(A 'serving' = palm size or ½ a cup of meat without bone)
e.g. ½ cup of savoury mince + 2 small lamb chops = 2 servings

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

***4. How often do you usually eat meat?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Beef mince dishes (rissoles, meatloaf, hamburger pattie) - 1 slice / patty / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beef or veal mixed dishes (casserole, stir-fry) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beef or veal (roast, chop, steak, schnitzel, corned beef) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lamb, hogget or mutton mixed dishes (stews, casserole, stir-fry) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lamb, hogget or mutton (roast, chops, steak) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pork (roast, chop, steak) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned corned beef - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

***5. How often do you usually eat these other meats?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sausage, frankfurter or saveloy - 1 sausage / frankfurter/ 2 saveloys	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bacon - 2 rashers	◯	◯	◯	◯	◯	◯	◯	◯	◯
Ham - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Luncheon meats or brawn - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Salami or chorizo - 1 slice / cube	◯	◯	◯	◯	◯	◯	◯	◯	◯
Offal (liver, kidneys, pate) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Venison/game - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

9. Poultry

***1. Do you eat poultry e.g. chicken, turkey or duck?**

- ◯ No
- ◯ Yes

***2. Do you remove the skin from chicken? (Please choose one only)**

- ◯ Not applicable
- ◯ Always
- ◯ Often
- ◯ Occasionally
- ◯ Never remove the skin from chicken

***3. On average, how many servings of chicken do you eat per week? (Please choose one only)**
(A 'serving' = palm size of chicken or ½ cup)
e.g. 1 chicken breast + 2 chicken drumsticks + 1 chicken thigh = 4 servings per week

- ◯ Not applicable
- ◯ Less than1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

***4. How often do you usually eat poultry?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Chicken legs or wings - palm size / ½ cup / 1 unit (wing, drumstick)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chicken breast - palm size / ½ cup / ½ breast	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chicken mixed dishes (casserole, stir-fry) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Crumbed chicken (nuggets, patties, schnitzel) - 1 medium / 4 nuggets	◯	◯	◯	◯	◯	◯	◯	◯	◯
Turkey or quail - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mutton bird or duck - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

10. Fish and Seafood

***1. Do you eat any type of fish or seafood?**

- ◯ No
- ◯ Yes

***2. On average, how many servings of fish and seafood (all types; fresh, frozen, tinned) do you eat per week? (Please choose one only)**
(A 'serving' = 80 - 120g or palm size or small tin (85g))
e.g. 1 fish fillet and 1 small tin of tuna = 2 servings per week.

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

3. How do you normally cook / eat fish? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Raw / I don't cook it
- ☐ Oven baked / Grilled
- ☐ Deep fried
- ☐ Shallow fry
- ☐ Micro waved
- ☐ Steamed
- ☐ Poached
- ☐ Smoked

EXPLORE Food Frequency Questionnaire

***4. How often do you usually eat seafood?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Canned Salmon - 1 small can (85-95g)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned Tuna - 1 small can (85-95g)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned Mackerel, sardines, anchovies, herring - 1 small can (85-95g)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Frozen crumbed fish (patties, fillets, cakes, fingers, nuggets) - 1 medium / 4 nuggets	◯	◯	◯	◯	◯	◯	◯	◯	◯
Snapper, Tarakihi, Hoki, Cod, Flounder - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Gurnard, Kahawai or Trevally - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lemon fish or Shark - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tuna - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Salmon, trout or eel - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

***5. How often do you usually eat seafood?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Shrimp, prawn, lobster or crayfish - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Crab or surumi - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Scallops, mussels, oysters, paua or clams - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pipi or cockle - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Kina - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Whitebait - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Roe - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Squid, octopus, calamari, cuttlefish - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

11. Fats and Oils

***1. Do you cook meat, chicken, fish, eggs and/or vegetables with fat or oil?**

- ◯ No
- ◯ Yes

2. What type(s) do you use most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Butter (all varieties)
- ☐ Margarines (all varieties)
- ☐ Cooking oils (all varieties)
- ☐ Lard, Dripping, Coconut oil, Ghee (clarified butter)
- ☐ Cooking spray

Other (please state)

***3. When you use fat or oil to cook, how many servings of fat or oil do you use per dish? (Please choose one only)**
(A 'serving' = 1 level teaspoon or 5 mL)

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 servings
- ◯ 4 servings
- ◯ 5 or more servings

***4. On average, how many servings of fat or oil do you use to cook per week? (Please choose one only)**

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-7 servings
- ◯ 8-10 servings
- ◯ 11-14 servings
- ◯ 15 or more servings

EXPLORE Food Frequency Questionnaire

12. Eggs

***1. Do you eat eggs?**

- ◯ No
- ◯ Yes

***2. On average, not counting eggs used in baking / cooking, how many eggs do you usually eat per week? (Please choose one only)**

- ◯ Not applicable
- ◯ Less than 1 egg
- ◯ 1 egg
- ◯ 2 eggs
- ◯ 3 eggs
- ◯ 4 eggs
- ◯ 5 or more eggs

***3. How often do you usually eat eggs?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Whole eggs (hard-boiled, poached, fried, mashed, omelette, scrambled) - 1 egg	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mixed egg dish (quiche, frittata, other baked egg) - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

13. Legumes

***1. Do you eat legumes e.g. chickpeas/dried peas, soybeans, dried/canned beans, baked beans, lentils or Dahl?**

- ◯ No
- ◯ Yes

***2. On average, how many servings of legumes (fresh, frozen, canned, dried) do you eat per week? (Please choose one only)**
(A 'serving' = ½ cup or 125g of cooked legumes)

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 servings
- ◯ 4-5 servings
- ◯ 6-7 servings
- ◯ 8 or more servings

***3. How often do you usually eat these legumes?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Soybeans - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tofu - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Dahl - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned or dried legumes, beans (baked beans, chickpeas, lentils, peas, beans) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Hummus - 2 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

14. Vegetables

***1. Do you eat vegetables?**

- ◯ No
- ◯ Yes

***2. On average, how many servings of vegetables (fresh, frozen, canned) do you eat per day? Do NOT include vegetable juices. (Please choose one only)**
(A 'serving' = 1 medium potato / kumara or ½ cup cooked vegetables or 1/2 cup of lettuce)
e.g. 2 medium potatoes + ½ cup of peas = 3 servings

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 servings
- ◯ 4 or more servings

***3. How often do you usually eat these vegetables?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Potato (boiled, mashed, baked, roasted) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pumpkin (boiled, mashed, baked, roasted) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Kumara (boiled, mashed, baked, roasted) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mixed frozen vegetables - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Green beans - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Silver beet, spinach - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Carrots - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sweet corn - 1 medium cob / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mushrooms - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tomatoes - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beetroot - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Taro, cassava or breadfruit - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

***4. How often do you usually eat these vegetables?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Green bananas (plantain) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sprouts (alfalfa, mung) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pacific Island yams - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Turnips, swedes, parsnip or yams - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Onions, celery or leeks - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cauliflower, broccoli or broccoflower - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Brussel sprouts, cabbage, red cabbage or kale - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Courgette/zucchini, marrow, eggplant, squash, kamo kamo, asparagus, cucumber - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Capsicum (peppers) - ½ medium / ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Avocado - ¼ avocado	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lettuce greens (mesculin, cos, iceberg) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other green leafy vegetables (whitloof, watercress, taro leaves, puha) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

15. Fruit

***1. Do you eat fruit?**

- ◯ No
- ◯ Yes

***2. On average, how many servings of fruit (fresh, frozen, canned or stewed) do you eat per day? Do NOT include fruit juice. (Please choose one only)**
(A 'serving' = 1 medium or 2 small pieces of fruit or 1/2 cup of chopped fruit)
e.g. 1 apple + 2 small apricots = 2 servings)

- ◯ Not applicable
- ◯ Less than one serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 or more servings

***3. How often do you usually eat these fruits?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Apple - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pear - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Banana - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Orange, mandarin, tangelo, grapefruit - 1 medium / 2 small	◯	◯	◯	◯	◯	◯	◯	◯	◯
Peach, nectarine, plum or apricot - 1 medium / ½ cup / 2 small	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mango, paw-paw or persimmons / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pineapple - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Grapes - ½ cup / 8-10 grapes	◯	◯	◯	◯	◯	◯	◯	◯	◯
Strawberries, other berries, cherries - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Melon (watermelon, rockmelon) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Kiwifruit - 1 medium / 2 small	◯	◯	◯	◯	◯	◯	◯	◯	◯
Feijoas - 1 medium / 2 small	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tamarillos - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sultanas, raisins or currants - 1 small box	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other dried fruit (apricots, prunes, dates) - 4 pieces	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

16. Drinks

***1. On average, how many drinks do you have per day? (Please choose one only) (A 'serving' = 250 mL or one cup/glass)**

- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-5 servings
- ◯ 6-8 servings
- ◯ 9-10 servings
- ◯ 11 or more servings

***2. How often do you usually have these drinks?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Instant soup (Cup of soup) - 250 mL / 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fruit juice (Just Juice, Fresh-up, Charlie's, Rio Gold) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fruit drink (Choice, Rio Splice) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Vegetable juice (tomato juice, V8 juice) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Iced Tea (Lipton Ice tea) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cordial or Powdered drinks (Thriftee, Raro, Vita-fresh) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Low-calorie cordial - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Energy drinks small-medium can (V, Red Bull) - 250-350 mL	◯	◯	◯	◯	◯	◯	◯	◯	◯
Energy drinks large can (Monster, Mother, Demon, large V) - 450-550 mL	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sugar-free Energy drinks (sugar-free V, Monster, Red Bull) - 1 small can	◯	◯	◯	◯	◯	◯	◯	◯	◯
Diet soft/fizzy/carbonated drink (diet sprite) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Soft/fizzy/carbonated drinks (Coke, Sprite) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sport's drinks (Gatorade, Powerade) - 1 bottle	◯	◯	◯	◯	◯	◯	◯	◯	◯
Flavoured water (Mizone, H2Go flavoured) - 1 bottle	◯	◯	◯	◯	◯	◯	◯	◯	◯
Water (unflavoured mineral water, soda water, tap water) - 250 mL / 1 cup/glass	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

17. Dressings and Sauces

***1. How often do you usually have these dressings or sauces?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Butter (all varieties) - 1 tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Margarine (all varieties) - 1 tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Oil (all varieties) - 1 tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cream or sour cream - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mayonnaise or creamy dressings (aioli, tartae sauce) - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Low fat/calorie dressing (reduced fat mayonnaise) - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Salad dressing (french, Italian) - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sauces (tomato, BBQ, sweet chilli, mint) - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mustard - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Soy sauce - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chutney or relish - 1 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Gravy homemade - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Instant Gravy (e.g. Maggi) - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
White sauce/cheese sauce - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

18. Miscellaneous - Cakes, Biscuits and Puddings

***1. How often do you usually eat these baked products?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Cakes, loaves, sweet muffins - 1 slice / 1 muffin	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sweet pies or pastries, tarts, doughnuts - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other puddings or desserts - not including milk-based puddings (sticky date pudding, pavlova) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Plain biscuits, cookies (Round wine, Ginger nut) - 2 biscuits	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fancy biscuits (chocolate, cream) - 2 biscuits	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

19. Miscellaneous

***1. How often do you usually eat these other foods?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Jelly - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Ice blocks - 1 ice block	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lollies - 2 lollies	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chocolate - including chocolate bars (Moro bars) - 1 small bar	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sugar added to food and drinks - 1 level tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Jam, honey, marmalade or syrup - 1 level tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Vegemite or marmite - 1 level tsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Peanut butter or other nut spreads - 1 level Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯
Brazil nuts or walnuts - 2	◯	◯	◯	◯	◯	◯	◯	◯	◯
Peanuts - 10	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other nuts (almonds, cashew, pistachio, macadamia) - 10	◯	◯	◯	◯	◯	◯	◯	◯	◯
Seeds (pumpkin, sunflower)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Muesli bars - 1 bar	◯	◯	◯	◯	◯	◯	◯	◯	◯
Coconut cream - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Coconut milk - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lite coconut milk - ¼ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Potato crisps, corn chips, Twisties - ½ cup / handful	◯	◯	◯	◯	◯	◯	◯	◯	◯

***2. Do you use salt in cooking?**

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Usually
- ◯ Always

***3. Do you use salt at the table?**

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Usually
- ◯ Always

EXPLORE Food Frequency Questionnaire

20. Miscellaneous - Takeaways

***1. On average, how often do you eat takeaways per week? (Please choose one only)**

- ◯ Never
- ◯ Less than 1 times
- ◯ 1-2 times
- ◯ 3-4 times
- ◯ 4-6 times
- ◯ More than 7 times

***2. How often do you usually eat these takeaway foods?**

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Meat pie, sausage roll, other savouries - 1 pie / 2 small sausage rolls or savouries	◯	◯	◯	◯	◯	◯	◯	◯	◯
Hot potato chips, kumara chips, french fries, wedges - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chinese - 1 serve	◯	◯	◯	◯	◯	◯	◯	◯	◯
Indian - 1 serve	◯	◯	◯	◯	◯	◯	◯	◯	◯
Thai - 1 serve	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pizza - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Burgers - 1 medium burger	◯	◯	◯	◯	◯	◯	◯	◯	◯
Battered fish - 1 piece	◯	◯	◯	◯	◯	◯	◯	◯	◯
Fried chicken (KFC, Country fried chicken) - 1 medium piece	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bread based (Kebab, sandwiches, wraps, Pita Pit, Subway) - 1 medium	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

21. Other

***1. Are there any other foods or drinks that you can think of that you have on a regular basis that was not covered by this questionnaire?**

- ◯ No
- ◯ Yes

EXPLORE Food Frequency Questionnaire

22. Other

1. Please list these foods and drinks including; the serving size, and how many times per week you eat or drink these items (e.g. Pizza, 4 slices, one time per week)

Appendix D. Assumptions made when entering the New Zealand Women's Food Frequency Questionnaire (NZWFFQ).

Participants choice	Item entered into FoodWorks
Milk	
Oat milk	So Good, Soy milk
Full cream milk	4% of the amount entered as cream, the rest milk, whole
Lite 1.5% fat and Trim 0.5% fat	Milk, lite 1.5% fat
Whole 3.3% fat and lite 1.5% fat	Milk, whole, 3.3% fat
Not applicable/nothing chosen	Milk, whole, 0m
Spreads	
Monounsaturated fat margarine e.g. olive, rice bran, canola oil	Margarine, Mono, 70% fat, Olivio Bertolli Classico
Polyunsaturated fat margarine e.g. sunflower oil spreads	Margarine, Poly, 60% fat, Sunrise
Light monounsaturated fat margarine e.g. Olivio Spread Light	Margarine, Mono, 55% fat, Olivani Light
Light polyunsaturated fat margarine e.g. Flora Spread Light	Margarine, Poly,50% fat, Flora Light
Plant sterol enriched margarine e.g. Pro Active, Logical spreads	Spread, Rice bran oil, Alfa one
Light plant sterol enriched margarine e.g. Pro Active spread light	Spread, Rice bran oil, Light, Alfa one
Butter and margarine blend e.g. Country soft, butter lea	Dairy blend, Butter Canola
Not applicable/nothing chosen	Margarine, Mono, 70% fat, Olivio Bertolli Classico, 0m
Oils	
Lard, dripping, coconut oil, ghee (clarified butter)	Lard
Cooking spray	Oil, composite
Not applicable/nothing chosen	Oil, composite, 0m
Butter and cooking oil	Oil, composite