The Metabolic Health of New Zealand Vegans

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

Master of Science

In

Nutrition and Dietetics

Massey University, Albany

New Zealand

Lucie Hill

2024

Abstract

Background: The popularity of a vegan diet is growing in New Zealand. Though there are potential nutrient deficiencies in a vegan diet, it is generally accepted that a vegan diet has greater metabolic benefits than a Western-style diet.

Objectives: This cross-sectional study aimed to explore the metabolic health status and dietary intake of adults who had been consuming a vegan diet for 2+ years.

Methods: Data were collected from The Vegan Health Research Programme. Participants completed questionnaires on demographic information, dietary practices and supplement use and a four-day food diary. Participants gave a blood sample for analysis of HbA1c, total cholesterol, LDL-C, HDL-C, Chol/HDL ratio, triglycerides and omega-3 index. Blood pressure, waist and hip circumference measurements were taken and body composition was measured using DXA.

Results: Participants (N=212) had a mean (SD) age of 39.5 (12.4) years and were predominantly female (73.1%). Mean (SD) metabolic health markers of HbA1c, total cholesterol, LDL-C, HDL-C, Chol/HDL ratio, triglycerides, diastolic blood pressure and waist circumference were all within normal ranges. Females had a normotensive mean (SD) systolic blood pressure of 114.2 (12.9) mmHg and males were just above the low-risk normotensive category at 124.4 (12.0) mmHg. The mean (SD) omega-3 index result of 3.1 (1.2) placed most participants (86.3%) in the high-risk category for heart disease. Saturated fat intakes for males and females were 8.1% and 9.1% of energy, within the recommended range of 8-10% of energy. Dietary fibre intakes were high, at mean (SD) 55.0 (17.8) g/day for males and 43.4 (12.8) g/day for females.

Conclusion: This is the first New Zealand study to examine the metabolic health and dietary intake of adult vegans. The results of metabolic health markers indicate that the vegan diet may confer cardioprotective benefits. The low omega-3 index of most participants is concerning, and warrants longitudinal research to assess the level of risk conferred by a low omega-3 index result in a population with no other metabolic risk factors. Dietary intake data shows the population is consuming saturated fat within the recommended range and high amounts of dietary fibre, which may go some way towards explaining the metabolic health status of the participants.

Acknowledgements

There are many people I owe my thanks to for making this research and my thesis possible. Firstly, I would like to thank my primary academic supervisor, Professor Pam von Hurst. Thank you for your support and mentorship since I first embarked on a new career as a nutritionist. You have been an inspiration to me and I will miss our chats. I would also like to thank my co-supervisors, Professor Cath Conlon and Dr Hajar Mazahery. I am truly grateful for all the time you spent reviewing this thesis, and your skillful editing has made it so much better. I would also like to thank Dr Karen Mumme for your assistance with statistical analysis. Thank you for your patience and your ability to explain complicated statistical concepts in plain English. Thanks also to Dr Jiayan Lin for your very helpful advice on thesis writing. Thank you to the other MSc students working on the Vegan Health Research Programme for all the moral support. Thank you to our participants, who so generously volunteered their time to participate in this study.

To my sisters and niece, thank you for the many hours of childcare and emotional support. To my Dad, thank you for always believing in me and encouraging me to take breaks. To my Mum, thank you for doing everything you could to support me in this project, from looking after my children to delivering food. To my husband James, thank you for believing in me and supporting me to follow my dream. I couldn't have done this without you. To Henry and Freddie, thank you for being so supportive of your Mum.

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List of Abbreviations

Abbreviation	Definition
ADA	American Diabetes Association
AGEs	Advanced glycation end products
AI	Adequate intake
ALA	Alpha-linolenic acid
AMDR	Acceptable macronutrient distribution ranges
BMI	Body mass index
BMR	Basal metabolic rate
BP	Blood pressure
CHD	Coronary heart disease
CKD	Chronic kidney disease
cm	Centimetre
CVD	Cardiovascular disease
DF	Dietary fibre
DHA	Docosahexaenoic acid
DPA	Docosapentaenoic acid
DXA	Dual X-Ray Absorptiometry
EAR	Estimated average requirement
EPA	Eicosapentaenoic acid
g	Gram
g/day	Grams per day
HbA1c	Glycated haemoglobin
hPDI	Healthful plant-based diet index
HDL-C	High-density lipoprotein cholesterol
kg	Kilogram
kj	Kilojoule
LA	Linoleic acid
LDL-C	Low-density lipoprotein cholesterol
m^2	Metres squared
mg	Milligram
mmHg	Millimetre of mercury
mmol/L	Millimole per litre
mmol/mol	Millimole per mole
µg	Microgram
MUFA	Monounsaturated fatty acid
PAL	Physical activity level
PDI	Plant-based diet index
PUFA	Polyunsaturated fatty acid
RCT	Randomised controlled trial
RDI	Recommended dietary intake
SD	Standard deviation
SDT	Suggested dietary target to reduce chronic disease risk
SFA	Saturated fatty acid
T2D	Type 2 diabetes

TC	Total cholesterol
TG	Triglycerides
TMAO	Trimethylamine N-oxide
uPDI	Unhealthful plant-based diet index
WC	Waist circumference
WHR	Waist-hip ratio
±	Plus-minus
>	Greater than
≥	Greater than or equal to
≤	Less than or equal to
<	Less than
%	Percentage

Chapter 1: Introduction

This chapter will explore the background of the growing popularity of the vegan diet and the implications for metabolic health. It will introduce the purpose of the research, aims and objectives, thesis structure, and finally the researchers' contributions.

1.1 Background

The popularity of a vegan diet is growing worldwide, for reasons such as environmental sustainability, health concerns and animal welfare concerns. Though there are nutrients of concern that may be in short-supply in a vegan diet, it is generally accepted that a vegan diet, with its emphasis on a variety of vegetables, fruit, legumes, and pulses, has greater metabolic benefits than a standard Western-style diet which includes animal products (Herpich et al., 2022). The food industry has responded to the demand for vegan products by creating a diverse range of novel plant-based meat and dairy analogues, which may be substituted for meat and dairy instead of traditional vegan protein sources such as tofu, legumes, and pulses. Many of these ultra-processed meat analogues contain added flavourings and emulsifiers to simulate the mouthfeel of eating meat, and the nutritional consequences of these products are as yet unknown (Wickramasinghe et al., 2021). Because of the growing popularity of these ultra-processed products the current vegan dietary intake in New Zealand may have a different nutrient profile to the vegan diets studied in older literature. To our knowledge, there has been no large-scale study of New Zealanders following a vegan diet. Data analysed from the 2018 NZ Attitudes and Values study, a longitudinal study of 47,000 participants, showed that 1.1% of the New Zealanders surveyed followed a vegan diet (Milfont et al., 2021). Little is currently known about the metabolic health and dietary intake of New Zealand vegans as there has been a lack of research focused on this population.

The World Health Organization (WHO) recommends a shift to a more plant-forward eating pattern lower in meat and processed foods as a strategy to curb the epidemic of non-communicable diseases such as cardiovascular disease (CVD) and type 2 diabetes (T2D) that are linked to a Western dietary pattern, with the added benefit of reducing greenhouse gas emissions (WHO, 2021). These non-communicable diseases are linked to increases in obesity, blood lipids and blood glucose concentrations, which are worsened by an unhealthy diet and a lack of physical activity. There is a perception of a vegan diet being a "healthy" diet, and many studies demonstrate that vegans have lower total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C), body mass index (BMI), and a lower incidence of CVD and T2D compared to meat eaters (Le & Sabaté, 2014). This may be due to the traditional vegan dietary pattern high in fibre, polyunsaturated fatty acids, fruit and vegetables, and lower in energy, total and saturated fat than many omnivorous diets (Selinger et al., 2022a).

This thesis will describe biomarkers used to assess metabolic health, such as HbA1c, TC, LDL-C, high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), and Chol/HDL ratio. It will explore the evidence for the effects of a vegan diet on these metabolic biomarkers and examine the metabolic health status of the New Zealand vegan population in relation to these biomarkers. This thesis will describe the omega-3 index, a less commonly used biomarker but one which gives an indication of cardiovascular risk status (Harris & von Schacky, 2004). The omega-3 index results of the participants will be reported and the implications discussed.

This thesis will describe the dietary intake of the New Zealand vegan population in relation to New Zealand dietary guidelines, with a focus on macronutrients, and nutrients with an established link to metabolic health, such as saturated fat and dietary fibre. Though vegan diets are often high in polyunsaturated fatty acids, they have no food source of the beneficial long-chain Omega-3 fatty acids docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), found primarily in oily fish. A low DHA and EPA intake is an independent risk factor for coronary heart disease mortality (Harris & von Schacky, 2004). This study will also describe the anthropometrical markers of the vegan participants and their relation to metabolic health, such as weight, waist circumference (WC), BMI, body fat percentage, and also blood pressure (BP). These markers contribute to a person's metabolic health status and risk profile for non-communicable diseases and are affected partly by dietary intake as well as physical activity and genetics. There is a well-established positive relationship between intakes of saturated fat and total and LDL-C, and a negative relationship between intakes of dietary fibre and total and LDL-C (Anderson et al., 2009; Sacks et al., 2017). As vegan diets are traditionally low in saturated fat due to the exclusion of meat, and high in dietary fibre due to high intakes of fruit, vegetables and wholegrains, the relationship between the intake of the New Zealand vegan population and their metabolic risk factors will be explored.

As cardiometabolic diseases such as CVD and T2D have now overtaken infectious diseases as the leading cause of death in the 21st century, it is important that the vegan diet is assessed for its effects on metabolic health, to provide guidance for people looking to move away from a Western dietary pattern and reduce their risk of developing diseases caused by poor cardiometabolic health (Kopp, 2019). The term “plant-based” has increased in usage with the popularity of the vegan diet. It may describe a plant-focused diet with small amounts of animal products occasionally or be used interchangeably with the term “vegan”, so for the avoidance of ambiguity this study will refer to a diet devoid of all animal products as a “vegan” diet.

1.2 Purpose of the study

The purpose of the Vegan Health Research Programme is to explore the general health and wellbeing of New Zealand vegans. This thesis report will focus on the metabolic health and dietary intake of New Zealand vegans and explore how their intake compares to the New Zealand reference ranges and nutrient reference values. This may provide some insight into the benefits and drawbacks of vegan diets. The growing vegan community may use this research to help guide them towards a nutritionally optimal vegan diet.

1.3 Aim

To explore the metabolic health and dietary intake of the New Zealand vegan population.

1.3.1 Objectives

1. To describe the New Zealand vegan population according to their metabolic health status including anthropometry, blood pressure, blood lipids, omega-3 index and blood glucose

2. To describe the dietary intake of people following a vegan diet in New Zealand

3. To explore the relationship between participant characteristics, dietary intake, and markers of metabolic health

1.4 Thesis structure

This thesis is divided into four chapters. Chapter One is an introduction to the background and purpose of the study, including the aim, objectives, and researchers’ contributions. Chapter Two is a literature review of the current and most relevant research concerning the metabolic health of vegans worldwide. It looks at the effects of a vegan diet on several markers of metabolic health such as blood lipids, blood pressure, HbA1c, omega-3 index and body composition. It also reviews the impact of specific nutrients on metabolic health such as dietary fibre and fatty acids. Chapter Three is the research manuscript which includes abstract, introduction, methods, results, discussion, and conclusion. Chapter Four, the final chapter, shows how the aim and objectives have been met, discusses the strengths, limitations, and impact of the research, and provides recommendations for further research.

Appendix A provides supplementary results such as the regression analysis results of metabolic biomarkers, omega-3 index and anthropometrical markers. Appendix B provides study materials such as the Participant Information Sheet, Food Diary Template, Health and Vegan Diet Demographic Questionnaire, and the Health and Vegan Diet Dietary Practices and Supplement Use Questionnaire.

1.5 Researchers' Contributions

Table 1.1

Summary of Researchers' Contributions

Author	Contribution to Thesis
Lucie Hill **MSc Nutrition and Dietetic student and primary author**	Reviewed the literature, involved in recruitment and data entry of the four-day food diaries, performed the statistical analysis and interpretation of the data, formulation of the results and main author of the thesis.
Professor Pamela von Hurst **Primary academic supervisor** **The Vegan Health Research Programme Principal Investigator**	Primary academic supervisor, developed the study design, acquired funding (Lottery Health Fund) and ethical approval, advised about data analysis. Revised and approved the thesis chapters and manuscript.
Professor Cathryn Conlon **The Vegan Health Research Programme Named Investigator** **Academic co-supervisor**	Academic co-supervisor, developed the study design, revised and approved the thesis chapters and manuscript.
Dr Hajar Mazahery **The Vegan Health Research Programme Named Investigator**	Academic co-supervisor, developed the study design and Vegan FoodWorks database, conducted data collection, revised and approved the thesis chapters and manuscript.
Dr Karen Mumme **Post-doctoral research fellow**	Assistance with statistical analysis.

I would like to acknowledge the Vegan Health Research Programme study team:

Table 1.2

The Vegan Health Research Programme Study Team

Associate Professor Kathryn Beck Named Investigator	Development of the vegan FoodWorks database, developed the study design
Rebecca Paul	Research Assistant
Owen Mugridge	Lab manager
Abril Clark, Chelsea Corkindale, Amelia Dunnett, Catherine Hassall, Fiona Li, Rebecca Pearce	Assistance with four-day food diary data entry, development of the Vegan FoodWorks database, participant recruitment and data collection

Chapter 2: Literature Review

2.1 Introduction

This literature review explores the characteristics of a vegan diet, the benefits of this dietary pattern and briefly, the risks. It is often assumed that a vegan diet is a healthy diet, so this review will explore the evidence for that. It will explore metabolic health, and the aspects of the vegan diet that contribute to metabolic health. It will define the biomarkers and anthropometry used to determine metabolic health and explore current research on the metabolic health of vegans. Lastly, it will briefly explore aspects of the diet that affect metabolic health. PubMed, Google Scholar, and Massey Discover were searched using combinations of the search terms in Table 2.1. A manual search was also undertaken using reference lists from systematic reviews and meta-analyses, nutrition guidelines, evidence papers and World Health Organization (WHO) reports. This review was limited to literature published in English.

Figure 2.1

Search Terms

Date searched: November 2022-September 2023

Search criteria:

Vegan* OR “plant-based” OR “meat alternative”

Metabol* OR cardiometabol*

Lipid* OR cholesterol OR HbA1c OR “type 2 diabetes” OR “blood pressure” OR “hypertension”

Filters: Scholarly (peer-reviewed) articles

Electronic Databases: PubMed, Google Scholar, Massey Discover

2.2 Characteristics of a Vegan Diet

A vegan diet is characterised by the elimination of all animal products from the diet. A vegan diet excludes meat, fish, dairy and eggs, and many vegans also exclude honey due to animal exploitation concerns. Animal protein is replaced with plant protein from soy, grains, legumes, pulses, nuts, and seeds. Plant proteins, except for soy, do not contain all the essential amino acids required by the human body in sufficient quantities, but plant proteins can be combined in the diet to attain all the essential amino acids (Insaf et al., 2019). These plant proteins, if eaten in conjunction with an abundance of vegetables and fruit, make a diet rich in fibre, vitamins, minerals, antioxidants, and unsaturated fatty acids. This dietary pattern is known to have beneficial effects on long term metabolic health (Herpich et al., 2022). Because of the elimination of animal products, vegan diets can be lower in saturated fat, energy, cholesterol, omega-3 fatty acids, vitamins D and B12, zinc and calcium than omnivorous diets (Craig, 2009).

A large meta-analysis of observational studies published between 1960 and 2018 looking at one or more cardiometabolic risk factors found that, compared to omnivores, vegans consumed less energy and saturated fat (Benatar & Stewart, 2018). These results were consistent across all countries in the studies except Taiwan. Vegan diets are more likely to have lower energy than standard Western diets, due to a lower intake of fat and a higher intake of dietary fibre (Benatar & Stewart, 2018; Termannsen et al., 2022). Even compared to vegetarians, vegan diets tend to be lower in saturated fat and cholesterol, and higher in dietary fibre (Craig, 2009).

A diet that favours plant protein over animal protein is associated with a lower risk of all-cause mortality and cardiovascular disease mortality, though not a lower risk of cancer mortality (Naghshi et al., 2020). This may be partly due to the different amino acid compositions of plant proteins, which are generally lower in sulfur-containing amino acids and branched-chain amino acids than animal proteins. The restriction of these is associated with increased longevity in rodent studies, though it is not clear if this applies to humans (Herpich et al., 2022). The higher ratio of saturated fat to unsaturated fat in animal protein compared to plant protein and high levels of heat-induced carcinogens in red meat may also contribute to a higher risk of cardiovascular disease and diabetes in red meat-eaters (Willett et al., 2019).

A traditional vegan dietary pattern, with a diverse amount of plant foods, may also promote a more diverse and stable microbiome, resulting in reduced risk of metabolic diseases. Fibre is fermented in the large intestine by certain types of bacteria into short-chain fatty acids, which are beneficial for immunity, intestinal health, lower blood glucose and cholesterol levels and overall health with anti-inflammatory effects (Haub & Lattimer, 2010; Salas-Salvadó et al., 2018). The genus *Bacteroides* is pro-inflammatory and linked to increased risk of metabolic syndrome and is found in abundance in the gut of those who consume animal products long-term due to its high tolerance of bile (Tomova et al., 2019). The genus

Prevotella is found in significant amounts in the gut of those following vegan diets and plant-rich, non-Western diets and is known to have anti-inflammatory effects (Tomova et al., 2019). An imbalance of gut microbiota is linked to some metabolic conditions such as obesity, atherosclerosis and type 2 diabetes, and a lack of microbial diversity is linked to arterial stiffness (Tomova et al., 2019). A study comparing the vegan gut microbiota to that of vegetarians and omnivores found vegans had a distinctly different gut profile to omnivores, but not markedly different from vegetarians. Vegans displayed a gut profile rich in species protective against metabolic disease and low in pathobionts, thereby reducing inflammation and improving glucose tolerance and lipid metabolism (Glick-Bauer & Ming-Chin, 2014).

Other benefits of a vegan diet may be attributed to the foods it includes, rather than to the exclusion of animal foods. The diet quality of a vegan diet is important, as many of the health benefits can be attributed to a high intake of vegetables, fruit, wholegrains and legumes (Hemler & Hu, 2019). Vegans, when compared to omnivores, generally eat more fruit, vegetables, legumes, pulses and nuts, all of which are a major part of a heart-healthy diet (Craig, 2009). Antioxidant chemicals and polyphenols found in plants can lower oxidative stress in the body, which helps to reduce the risk of metabolic disorders (Clemente-Suárez et al., 2023). This contrasts with a Western-style diet, composed of high intakes of saturated fat, red and processed meat, refined carbohydrates, added sugars, sodium and ultra-processed foods and low intakes of wholegrains and fruit and vegetables. This dietary pattern has been linked with an increased risk of developing obesity, CVD, T2D, and some cancers, partly due to the persistent low-grade inflammation that is an effect of the dietary pattern (Clemente-Suárez, 2023).

This begs the question whether it is necessary to follow a strict, healthful vegan diet for optimal metabolic health, or whether the same health benefits can be achieved following a plant-rich diet that includes small amounts of animal products, such as the Mediterranean diet or the Eat-*Lancet* Commission Planetary Health Diet for sustainable food systems (Willett et al., 2019). The Mediterranean diet was first studied by Ancel Keys in the 1950s, after observing the high rates of heart disease among American businessmen, and the comparatively low rates of heart disease in the countries of the Mediterranean. The dietary pattern of the seven countries studied was characterised by a low intake of animal fat and animal products, high intakes of plant foods and unsaturated fats, specifically olive oil (Delarue, 2022). The Planetary Health Diet is mostly composed of wholegrains, vegetables, fruits, legumes, nuts and unsaturated oils, a low to moderate amount of seafood and poultry, and little to no red and processed meat, added sugar, refined grains and starchy vegetables (Willett et al., 2019). A later review of the Planetary Health Diet found there may be micronutrient shortfalls in zinc, B12, iron, and calcium in populations with increased nutrient needs such as women of reproductive age. The review recommended increasing the proportion of animal-source foods from 14% to 26% of total energy and reducing phytate-rich foods (Beal et al., 2023). Further research is needed to determine whether a vegan diet confers any additional health benefits over and above the Mediterranean diet, Eat-*Lancet* reference diet or any similar plant-rich dietary pattern such as many traditional diets.

Vegan diets can vary widely in their composition of macronutrients and energy intake, therefore planning and individual nutrition advice are helpful to ensure a healthful diet. The position of the American Dietetic Association is that a well-planned vegan diet is appropriate for all stages of the life cycle, including pregnancy and lactation (Craig & Mangels, 2009). Due to the exclusion of animal products, a vegan diet that is not carefully planned or appropriately supplemented risks deficiencies in several vitamins and minerals, especially iron, calcium, zinc, omega-3 fatty acids and vitamins D and B12 (Craig, 2009). These deficiencies can have long-term effects on bone, brain, and reproductive health.

2.3 Metabolic Health

There is no one definition of metabolic health, but at a minimum metabolic health can be defined as the absence of metabolic syndrome. To have good metabolic health, a person's body will optimally respond to food, avoiding inappropriate postprandial responses which can over time lead to chronic inflammation, atherosclerosis, and impaired glucose metabolism or insulin resistance. Biomarkers should be below the cut-off points where lifestyle or pharmacological intervention is advised (Araujo, 2019). Metabolic syndrome, or "syndrome X", is a cluster of metabolic abnormalities which often occur together, and lead to an increased risk of developing CVD and T2D. Abdominal obesity is a central factor of metabolic syndrome and may precede the other factors, which are impaired glucose regulation, hypertension and atherogenic dyslipidaemia (Huang, 2009). Blood lipid concentrations, BP, waist-hip ratio (WHR), WC, BMI and HbA1c levels are all important indicators of metabolic health status, and looked at together can indicate a person's risk of developing chronic diseases.

2.3.1 Cardiovascular Disease

Cardiovascular disease (CVD) is the leading cause of death worldwide, responsible for around 32% of all deaths annually (WHO, 2017). Unhealthy diet, along with smoking, harmful alcohol use and physical inactivity, is one of the primary modifiable risk factors for this disease. The European Heart Network estimates that dietary factors play the largest contribution to CVD mortality of all these behavioural risk factors (Wilkins E, 2017).

Meta-analyses of prospective studies show mixed results regarding the risk of developing CVD for those following a vegan diet (Benatar & Stewart, 2018; Kaiser et al., 2021; Key et al., 1999). An analysis of five prospective studies found that death from heart disease was 26% lower in vegans than in meat eaters after 10 years, when adjusted for age, sex, and smoking status. There were far fewer vegans (n=1163) than meat-eaters (n=48,364) in the study though, and in one of the studies vegetarians who did not consume dairy were reclassified as vegans (Key et al., 1999). The lower rate of death from heart disease is thought to be mainly due to the vegans' overall lower serum cholesterol levels. Benatar and Stewart also concluded that plant-based diets were associated with a lower risk of CVD and diabetes (Benatar & Stewart, 2018). One factor that may add to the higher rates of CVD in meat-eaters is thought to be their higher plasma levels of trimethylamine N-oxide (TMAO), a metabolite produced by gut bacteria to break down red meat. Higher levels of TMAO in a large observational study were linked to increased risk of CVD, chronic kidney disease (CKD) and T2D. Intake of fish, poultry and eggs in this study were not significantly linked to higher rates of CVD (Wang et al., 2022). The reason for this increased risk with red meat consumption is still not clear, though experimental studies have pointed to decreased reverse cholesterol transport, vascular inflammation, endothelial dysfunction and macrophage foam cell formation as possible contributing factors (Wang et al., 2022). A recent meta-analysis of data from over 7000 vegan participants found no significant increased or decreased risk of primary cardiovascular events between vegans and non-vegans, though the authors noted the studies in the meta-analysis were of poor quality when assessed using the GRADE method (Kaiser et al., 2021). Another systematic review and meta-analysis of dietary interventions found little difference in cardiometabolic markers between those following a vegan diet and the American Diabetes Association (ADA) dietary guidelines (Selinger et al., 2022b). The ADA guidelines essentially promote a healthy plate model, where half the plate is filled with non-starchy vegetables, a quarter of the plate is filled with lean protein such as chicken, fish or plant protein, and a quarter of the plate contains a wholegrain carbohydrate source or starchy vegetable. The guidelines also promote unsaturated plant oils over saturated fats and promote water or unsweetened tea or coffee as beverages.

There are also reports of an increased risk of ischaemic stroke for those following a vegan diet (Kaiser et al., 2021). Though increased fruit and vegetable intake is protective against stroke, there may be nutrient deficiencies relating to lack of animal products that need further investigation (Tong et al., 2019). Animal protein, cholesterol, and long-chain Omega-3 fatty acids are thought to be protective against stroke, and these are all absent from the vegan diet (Sauvaget et al., 2004).

These mixed results regarding CVD outcomes show a need for more well-designed studies considering potential confounding factors such as healthier lifestyle choices, ensuring the effects of a vegan diet on cardiometabolic outcomes are clearly shown. More studies are also needed comparing vegan diets with healthy omnivorous dietary patterns. This will help to discern whether a vegan diet confers cardiometabolic benefits over and above the healthy eating guidelines recommended by health authorities.

2.4 Biomarkers and Anthropometrical Ranges Used to Assess Metabolic Health

Several biomarkers can be examined to gain a picture of the metabolic health of vegans (Tables 2.1 and 2.2). Serum biomarkers which can be investigated include HbA1c, total cholesterol, LDL-C, triglycerides, HDL-C, and Chol/HDL ratio. Omega-3 index can be analysed from a blood spot showing the amount of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) in the red blood cell membrane. Anthropometrical measurements which can also be used to give a picture of metabolic health are systolic and diastolic blood pressure, BMI, WC, WHR, and body fat percentage. Looked at together these biomarkers and measurements can give an objective indication of the effects of the vegan diet on metabolic health.

Table 2.1

Biomarker Reference Intervals for Adults

Biomarker	**Range**
HbA1c[1]	
Non-diabetic	≤40 mmol/mol
Pre-diabetes	41-49 mmol/mol
Diabetes	≥50 mmol/mol
Total cholesterol[1]	<5 mmol/L
Triglycerides[1]	<2.0 mmol/L
HDL cholesterol[1]	>1.00 mmol/L
LDL cholesterol[1]	<3.4 mmol/L
Chol/HDL ratio[1]	<4.5
Omega-3 index[2]	
Low risk	>8%
Intermediate risk	4-8%
High risk	<4%

[1] (Mansour, 2023)

[2] (Harris, 2007)

Table 2.2

Anthropometrical and Blood Pressure Reference Intervals for Adults

	Range
Systolic and diastolic blood pressure (mmHg)	
normal[1]	<120/80
hypertension[2]	≥140/90
Body mass index (kg/m²)[3]	
underweight	<18.50
normal range	18.50-24.99
overweight	25.00-29.99
obese	≥30.00
Waist circumference (cm)[3]	
Males – lower risk	<94
Females – lower risk	<80
Males – increased risk	94-102
Females – increased risk	80-88
Males – higher risk	>102
Females – higher risk	>88
Waist-hip ratio[3]	
Males – increased risk	≥0.90
Females – increased risk	≥0.85
Males – low risk	<90
Females – low risk	<0.85
Body fat (%)[4]	
Males - high body fat	≥25
Females – high body fat	≥30

[1] The sixth report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure. Arch Intern Med 1997; 157: 2413-2446

[2] World Health Organization, 2023

[3] World Health Organization. (2015). Waist circumference and waist-hip ratio: Report of a WHO expert consultation

[4] Okorodudu et al., 2010

2.4.1 Lipids

Dyslipidaemia is a condition where blood levels of lipids, such as high-density lipoproteins (HDL-C), low-density lipoproteins (LDL-C) and triglycerides (TG), are outside the recommended ranges. There are no symptoms, but over time high levels of LDL-C and low levels of HDL-C can lead to a buildup of plaque on the artery walls, a condition called atherosclerosis. Dyslipidaemia is a primary risk factor for CVD, and elevated plasma total cholesterol (TC), LDL-C and TG are positively associated with CVD risk (Yokoyama, 2017).

2.4.2 Effects of a Vegan Diet on Plasma Lipids

Vegan diets are thought to have a beneficial effect on plasma lipids through several mechanisms. Vegan diets are generally high in fibre due to the large amounts of plant foods eaten, and vegan diets are higher in fibre than lacto-ovo vegetarian diets (Craig & Mangels, 2009). Plant-rich vegan diets are high in soluble fibre, which increases bile acid excretion by the body, reducing the amount of serum total and LDL-C (Hartley et al., 2016). Short-chain fatty acids, produced by bacterial fermentation of fibre in the colon, inhibit de novo cholesterol synthesis by the liver and small intestine (Haub & Lattimer, 2010). Dietary cholesterol also has a small effect on plasma lipid levels, and vegan diets are free from cholesterol as this is only found in animal foods. Another important cholesterol-lowering mechanism is the generally lower levels of dietary saturated fat in a vegan diet, as a diet high in saturated fat is thought to increase plasma cholesterol levels (Kashyap et al., 2022). Conversely, polyunsaturated fatty acids (PUFAs) decrease lipogenesis, and vegans may often consume a higher amount of PUFAs than omnivores (Davey et al., 2003; Kersten, 2001). Plant sterols are similar molecules to cholesterol but are found in vegetable oils, nuts, and seeds. Their intake is negatively associated with plasma cholesterol concentrations, as the sterols compete with cholesterol for absorption. Soy intake is also associated with decreased cholesterol synthesis and increased LDL-C resistance to oxidation (Ferdowsian & Barnard, 2009).

Observational studies have shown an overall trend of lower TC and LDL-C amongst vegan subjects. A large meta-analysis of observational studies found vegans had significantly lower LDL-C compared to omnivores (Benatar & Stewart, 2018). The same authors conducted an observational study of 25 vegan subjects compared with 25 age-matched omnivores eating a normal diet in New Zealand. The vegans had significantly lower TC (3.6 vs. 4.7 mmol/L, $P<0.0001$), LDL-C (1.7 vs. 2.6 mmol/L, $P<0.0001$), and TG (0.67 vs. 0.85 mmol/L, $P<0.0001$) than the omnivores. Notably, 83% of the vegan participants consumed only unprocessed food (Benatar & Stewart, 2017). A meta-analysis of vegan and vegetarian diets compared with omnivores found that vegans were more likely to have significantly lower TC and LDL-C than omnivores (Dinu et al., 2017). Vegan diets have also been found to have a larger beneficial effect on plasma lipids than lacto-ovo vegetarian diets (Yokoyama et al., 2017). A small Finnish study comparing vegans to non-vegetarians found that vegans had 20% lower serum TC and 25% lower LDL-C than non-vegetarians (Elorinne et al., 2016).

This cholesterol-lowering effect of vegan diets is also seen in randomised controlled trials (RCTs). Clinical trials using vegan dietary interventions have shown that vegan diets lower TC and LDL-C by modest amounts. A meta-analysis of vegan dietary interventions showed that vegan diets resulted in a mean 0.30 mmol/L reduction in TC and a reduction of 0.24 mmol/L in LDL-C, and no difference in HDL-C or TG compared to control diets (Termannsen et al., 2022). Another meta-analysis of RCTs comparing the blood lipids of those following vegan and vegetarian diets with omnivores concluded that vegan and vegetarian diets were associated with reduced concentrations of TC and LDL-C (Koch et al., 2023). In one 18-week RCT of 254 participants, TC and LDL-C decreased in the vegan diet intervention group by 0.4 and 0.3 mmol/L, with no significant change in the Chol/HDL ratio (Mishra et al., 2013).

A review of 27 RCTs of vegan and vegetarian dietary interventions concluded that vegan dietary interventions are effective for lowering TC and LDL-C concentrations by 15 to 25%. Dietary interventions that allowed small amounts of lean meat were less effective at lowering TC and LDL-C, though a combination dietary intervention (vegetarian with added fibre, soy and nuts) was associated with a decrease of 20 to 35% (Ferdowsian & Barnard, 2009).

HDL-C may be likely to decrease on a vegan diet (Selinger et al., 2022a; Wright et al., 2017). This may be a concern for metabolic health as low levels of HDL-C have an atherogenic effect on the body. HDL-C has an important role in preventing atherosclerosis by removing cholesterol from foam cells in the vascular wall, thus reducing vascular wall inflammation and inhibiting the oxidation of LDL-C (Barter, 2005). The Chol/HDL ratio measurement considers the positive influence of a higher HDL-C on the overall risk profile and is strongly predictive of ischaemic heart disease mortality (Prospective Studies Collaboration, 2007). The reason for the reduction in HDL-C for some on a vegan diet may be due to a high consumption of refined carbohydrates. Observational studies suggest that vegans' overall lower levels of HDL-C are not associated with poor cardiovascular health (Ferdowsian & Barnard, 2009). A meta-analysis of vegan dietary interventions of 12 weeks or longer found no change in HDL-C levels over that time (Termannsen et al., 2022). In contrast, Mishra et al found HDL-C decreased in the intervention group and increased in the control group, which may be partly due to the effect of higher weight loss in the intervention group (Mishra et al., 2013).

Triglycerides (TG) are the most common type of fat in the body, used to store excess energy from food. High levels of TGs in the blood are linked with elevated risk of atherosclerotic CVD (Budoff, 2016). Observational studies have reported conflicting results regarding the effect of a vegan diet on TGs. An umbrella review of meta-analyses of clinical and observational studies concluded that TGs may be likely to increase on a vegan diet (Selinger, 2022). A meta-analysis of observational studies concluded that vegans had TG levels -0.14 mmol/L less than omnivores (Benatar & Stewart, 2018). Another meta-analysis of cross-sectional and observational studies of vegetarians and vegans reported them to have non-significant lower TG levels than omnivores (Dinu et al., 2017).

Randomised controlled trials of vegan dietary interventions have also reported conflicting results. This may be due to the composition of the intervention diet, as diets high in refined carbohydrates may increase TG levels, and diets rich in fibre and low-glycaemic index foods may decrease TGs (Ferdowsian & Barnard, 2009). Low-fat vegan dietary interventions may also influence blood lipid metabolism resulting in increased secretion of TGs to the blood (Selinger et al., 2022a). Koch et al reported no significant difference in TGs in a meta-analysis of RCTs (Koch et al., 2023). In a large-multi-centre vegan dietary intervention RCT, TGs increased in the intervention group though participants were asked to favour low-glycaemic index foods (Mishra et al., 2013).

2.4.3 Blood Pressure

Hypertension is a state of persistently high arterial blood pressure (BP), when the force of blood pushing on the arterial walls is higher than ideal, and the heart must work harder to pump blood around the body. Hypertension affects roughly a quarter of the world's population and is a significant independent risk factor for CVD and CKD. Patients with hypertension are more likely to develop T2D or suffer a stroke (Lee et al., 2020). A 6 mmHg reduction in BP is expected to reduce cardiovascular risk by around 12%, and even a 2 mmHg reduction in systolic BP substantially reduces the risk of cardiovascular diseases (Benatar, 2018; Lee, 2020).

2.4.4 Effects of a Vegan Diet on Blood Pressure

There are several aspects of vegan diets which may contribute to lowering BP. Plant protein intake is inversely correlated with BP (Elliott et al., 2006). Animal protein is usually accompanied by saturated fatty acids (SFAs), but plant protein in its whole state includes fibre and phenolic compounds, which improve vascular endothelial function (Laouali et al., 2021). A diet higher in potassium (i.e., rich in fruit and vegetables) has a beneficial effect on BP, and intake of polyphenols has a negative correlation with BP (Dasinger et al., 2020; Tomé-Carneiro & Visioli, 2023). Vegetables such as beetroot and green leafy vegetables are high in nitrate, and consumption of a diet high in nitrate is associated with significantly lower blood pressure (Bondonno et al., 2021). Vegans also have a lower BMI generally than omnivores, which has a BP-lowering effect (Appleby et al., 2002; Pettersen et al., 2012).

Despite the beneficial effects of increased plant protein, fruit, and vegetable intake, the evidence is conflicting as to whether a vegan diet lowers BP. A recent umbrella review of the health benefits and risks of a vegan diet found no effect on systolic and diastolic BP when compared to a non-vegan diet (Selinger et al., 2022a). A meta-analysis of observational studies also found no difference in BP between vegans and omnivores in Asian studies, but lower systolic (-5.87 mmHg) and diastolic (-3.19 mmHg) BP in non-Asian studies (Benatar & Stewart, 2018). The authors suggested that this may be due to an omnivorous dietary pattern in Asia that focuses less heavily on animal products than the average omnivorous Western diet. Rees et al found no consistent effects of the vegan diet on BP for primary prevention of CVD in a systematic review (Rees et al., 2021). A meta-analysis of vegan dietary interventions lasting 12 weeks or more found the vegan diet had no effect on BP in that time frame (Termannsen et al., 2022). A meta-analysis of 11 clinical trials that compared vegan diets with less restrictive diets found no significant difference in systolic and diastolic BP between vegans and other groups when looking at the overall population. When looking at participants who were hypertensive at baseline there was a reduction in systolic and diastolic BP in the vegan dietary intervention group (Lopez et al., 2019).

On the other hand, a systematic review of RCTs on the effects of vegan and vegetarian diets on blood pressure found that a vegan diet resulted in a greater reduction in BP than a lacto-ovo vegetarian diet, with a reduction of -3.12 mmHg systolic BP and -1.75 mmHg for diastolic BP (Lee et al., 2020). The EPIC-Oxford study analysed the BP of over 11,000 participants on vegan, vegetarian, pescetarian and meat-eating diets, and found that vegans had the lowest BP out of all the groups, with meat-eating participants having the highest BP. Values were adjusted for age and taken from participants without self-reported hypertension. The authors found a difference between meat-eaters and vegans of 4.2 and 2.6 mmHg systolic and 2.8 and 1.7 mmHg diastolic BP for men and women respectively. Much of this difference was attributable to a lower BMI in the vegan cohort. It was also noted that vegans had the lowest intake of alcohol and sodium among the groups which may be another contributing factor (Appleby et al., 2002). Data analysed from 500 participants of the Adventist Health Study-2 also found that vegans had lower systolic and diastolic BP than omnivores, which the authors said was partly attributed to the vegans' lower BMI and higher intake of fruit and vegetables (Pettersen et al., 2012).

2.4.5 HbA1c

HbA1c, also known as glycated haemoglobin, is a blood test that measures the average amount of glucose in a person's blood over the previous three months, which is the approximate life cycle of a red blood cell. It is measured in mmol/mol and is and used as a tool to diagnose diabetes.

2.4.6 Effects of a Vegan Diet on HbA1c

There are aspects to a vegan diet that may contribute to a healthy HbA1c level and a reduced risk of developing T2D, most of which are related to a high intake of plant foods. Diets with a high intake of vegetables, wholegrains, nuts and legumes are known to improve glycaemic control and lower risk of T2D (Craig & Mangels, 2009). A diet naturally rich in polyphenols, the chemical compounds found in plant foods, is associated with improved glucose metabolism, HbA1c and reduced risk of T2D (Cao et al., 2019). Magnesium, a mineral found in many plant foods, is important for glucose and insulin metabolism (Volpe, 2013). Diets high in viscous and soluble fibre improve levels of post-prandial blood glucose and long-term glucose metabolism (Haub & Lattimer, 2010). Substituting animal sources of protein for plant protein also has the effect of increasing the amount of fibre eaten. Many studies have also noted a negative association between consumption of red and processed meat and T2D (Craig et al., 2021). The weight-lowering effects of a vegan diet may also help reduce the risk of T2D, which is strongly associated with obesity (American Diabetes Association, 2020).

Although vegan diets are often higher in carbohydrates and lower in protein than omnivorous diets, intervention trials show a glucose-lowering effect or no increase in HbA1c (Pollakova et al., 2021). This may be due to the high levels of dietary fibre in a traditional vegan diet, which flattens out the post-prandial spike in blood glucose by slowing down gastric emptying time and starch digestion (Kashyap et al., 2022). One meta-analysis of vegan dietary interventions showed a reduction in HbA1c of 0.18 percentage points in vegan diets compared with control diets (conventional diabetes diets), and a reduction of 0.38 percentage points in participants with T2D, though there was no adjustment for the effect of weight loss (Termannsen et al., 2022). In Mishra's 18-week RCT of a vegan dietary intervention, HbA1c decreased by 0.7 percentage points in the intervention group and 0.1 percentage points in the control group (Mishra et al., 2013). A systematic review of observational and RCTs concluded that a vegan diet was associated with reduced incidence of T2D in the general population, and improved glucose homeostasis in diabetic populations (Pollakova et al., 2021).

Evidence from RCTs indicates a vegan diet has a positive effect on HbA1c in people with T2D. A 74-week study of T2D patients found that a low-fat vegan diet was more beneficial than a conventional diabetes diet for reducing glycaemia and plasma lipids (Barnard et al., 2009). A systematic review of controlled studies also found that a vegan diet was associated with improvements of HbA1c, weight, TC and LDL-C in participants with T2D compared to control diets including diabetes reference diets (Toumpanakis et al., 2018). The BROAD study, a 12-week whole-food pant-based diet intervention in Gisborne, New Zealand recruited participants who were obese or overweight and had one of either T2D, ischaemic heart disease, hypertension or hypercholesterolaemia. The intervention group attended twice-weekly meetings and were placed on a whole-food vegan diet with no energy restriction. The intervention group had a mean reduction in HbA1c of 5 mmol/mol after 6 months, and the control group had a reduction of 2 mmol/mol in the same time period (Wright et al., 2017).

2.4.7 Weight, Body Mass Index and Body Fat Percentage

Body mass index (BMI) is a tool used to assess body mass that is useful to assess weight-related issues at a population level. It divides weight (kgs) by height (m^2) but does not take body composition into account. Obesity rates are increasing in New Zealand as well as across the world. The 2020/21 New Zealand Health Survey found that obesity has increased in adults and children since 2019/20, with 34.4% of adults obese, up from 31.2% in 2019/20. The percentage of children with obesity rose from 9.5% to 12.7% in the same period (Ministry of Health, 2021).

Waist circumference and waist-hip ratio are also important tools to assess metabolic health as they can indicate abdominal obesity, which is one of the criteria used to diagnose metabolic syndrome. Fat distribution can vary widely from person to person, and these differences in fat distribution are not clear using BMI as an assessment tool. Abdominal obesity is associated with an increased risk of myocardial infarction, stroke and premature death (World Health Organization, 2008). An increase in visceral adipose tissue is associated with decreased glucose tolerance, reduced insulin sensitivity, and abnormal lipid profiles, thus leading to increased risk of CVD and T2D (World Health Organization, 2008).

Vegan diets may be beneficial for weight reduction among the general population as well as being an effective weight reduction diet for persons at high risk of CVD or T2D (Selinger et al., 2022b). The gut microbiome composition of vegans may also play some part in maintaining a lower BMI, as the ratio of *Bacteroidetes:Firmicutes* is a predictor of obesity. A high *Bacteroidetes:Firmicutes* ratio, such as that seen on a high fibre, plant-based diet, may aid weight loss or maintenance by reducing the energy harvested from food (Tomova et al., 2019). A diet high in fibre also aids with body weight control by triggering satiety cues and reducing energy intake (Salas-Salvadó et al., 2018).

Observational studies consistently report that vegans have a lower BMI than omnivores. Data from the Adventist Health Study showed that vegans had a mean BMI of 23.6 kg/m² (normal range), lacto-ovo-vegetarians had a mean BMI of 25.7 kg/m² (overweight range), and omnivores had a mean BMI of 28.8 kg/m² (overweight range) (Orlich & Fraser, 2014). A large meta-analysis of cross-sectional studies found that vegans consumed 11% less energy per day than omnivores, which would also contribute to the generally lower BMI of vegans compared to omnivores (Benatar & Stewart, 2018). The EPIC-Oxford study found that vegans had the lowest BMI of all the dietary cohorts, with a mean BMI of 22.5 and 21.9 kg/m² for men and women respectively. Vegetarians (mean 23.5 and 22.7 kg/m² for men and women) and fish eaters (mean 23.6 and 22.9 kg/m² for men and women) had a similar BMI, and meat-eaters had the highest BMI of all the groups with a mean 24.9 kg/m² for men and 24.3 kg/m² for men and women (Davey et al., 2003). Another large meta-analysis of vegetarian and vegan diets concluded that vegans had a BMI on average 1.72 kg/m² lower than omnivores. Vegetarians also had a lower BMI than omnivores (-1.49 kg/m²) but slightly higher than vegans (Dinu et al., 2017).

Vegan clinical intervention studies have shown a trend towards weight loss in the intervention groups which varies in significance depending on the control diet. The BROAD study found a significant 4.4 kg/m² reduction in BMI after 6 months, dropping slightly to 4.2 kg/m² after 12 months for the intervention group, and a non-significant reduction of 0.5 kg/m² in the control group. Barnard et al. compared vegan, vegetarian, and conventional diabetes diets on participants with T2D and found weight loss was slightly more in the vegan group (4.4 kg) compared to the conventional diet group (3.0 kg) (Barnard et al., 2009). A systematic review and meta-analysis comparing the effectiveness of very low-energy diets or low-fat vegan diets on T2D found a trend towards improved weight loss in both diets but no statistically significant changes in weight and BMI in the vegan diet group (Kashyap et al., 2022). The GEICO study, a multi-centre RCT of a low-fat vegan diet intervention in the workplace reported a 2.9 kg reduction in body weight in the vegan intervention group compared to a 0.06 kg reduction in the control group (Mishra et al., 2013). There was no restriction on energy intake.

Body fat percentage can be accurately assessed using Dual X-Ray Absorptiometry (DXA). This gives a more accurate picture of metabolic health as it reports on the muscle mass and fat mass of the subject, as well as the bone density. There is no consensus in the literature on the cut-off that constitutes a high body fat percentage, though many studies use around 25% body fat for males and 30-35% for females. A normal body weight (BMI <25 kg/m²) and a high body fat percentage (>30%) are linked to an increase in metabolic abnormalities. This classification has been termed "normal weight obesity" by some researchers and has been found to be linked to higher risk of CVD and all-cause mortality (Oliveros et al., 2014; Romero-Corral et al., 2010). Women with normal weight obesity were found to be 2.2 more times more likely to die from CVD than women with a normal body fat percentage (Oliveros et al., 2014). People with normal weight obesity were found in one study to have four times the prevalence of metabolic syndrome than those of a similar weight with a normal body fat percentage. In women, normal-weight obesity was an independent risk factor for CVD mortality (Romero-Corral et al., 2010).

2.5 Vegan Dietary Patterns

It is important when looking at vegan diets to consider the dietary pattern, as we do not eat foods in isolation. A shift to a more plant-rich diet is recommended by many health authorities to reduce the risk of chronic diseases, yet there is growing evidence that a plant-based diet high in unhealthful processed plant foods is not beneficial for metabolic health.

Although replacing animal sources of fat with plant sources of fat is beneficial for metabolic health, a plant-based diet high in unhealthful plant foods such as sugar-sweetened beverages and refined carbohydrates is associated with an increased risk of coronary heart disease (CHD) and T2D. Many studies on the healthfulness of vegan diets have grouped all plant foods together, not dividing participants by diet quality. To further examine the effects of a healthful or unhealthful plant-based diet (though not strictly vegan) on the risk of CHD and T2D, Satija et al. created a plant-based diet index (PDI), a healthful plant-based diet index (hPDI), and an unhealthful plant-based diet index (uPDI). The PDI positively weights plant foods, irrespective of quality and negatively weights animal foods. The hPDI positively weights plant foods associated with health benefits, such as wholegrains, legumes, soy, vegetables, and fruit. The uPDI positively weights foods associated with increased risk of chronic diseases, such as sugar-sweetened beverages, refined grains, and sweets, and negatively weights healthy plant foods and animal foods. These dietary indices were used to analyse food frequency questionnaires from over 200,000 participants in the Nurses' Health Study and the Health Professionals Follow-up Study. The analyses found that adherence to an overall plant-based diet was modestly associated with decreased CHD risk, and the healthful PBDI was more strongly associated with decreased risk of CHD. Adherence to an unhealthy plant-based diet was associated with increased CHD risk (Satija et al., 2017). The PDI and hPDI were both associated with an inverse risk of T2D, but the inverse risk was stronger for the healthful version of the plant-based diet, with a 34% reduced risk of developing T2D. The uPDI was associated with a 16% increased risk of developing T2D (Satija et al., 2016).

In addition to increased risk of T2D and CHD, unhealthy vegan diets are associated with other health risks. Less healthy plant foods such as fries, sugar-sweetened beverages and refined grains are associated with increased CVD risk (Hemler & Hu, 2019). Processed, refined foods and foods cooked at high temperatures contain high concentrations of advanced glycation end products (AGEs), a group of molecules formed by non-enzymatic reactions between amino acids and reducing sugars. AGEs can contribute to oxidative stress in the body and increase production of pro-inflammatory cytokines, both of which are linked to the development of T2D and CVD (Clemente-Suárez et al., 2023).

2.6 The Relationship of Dietary Intake to Metabolic Health

This section will review the relationships between nutritional factors that impact on metabolic health such as different types of fatty acids and dietary fibre.

2.6.1 Saturated Fats

Saturated fatty acids (SFAs) have no double bonds between carbons as they are saturated with hydrogen and are solid at room temperature. They occur naturally in the meat of land animals and in coconut and palm oils. They are not considered to be an essential fat as they can be synthesised by the body. SFAs are widely regarded as being a major risk factor for heart disease, and public health advice is to limit the amount of saturated fat eaten to less than 10% of energy intake, and replace saturated fat with unsaturated fats (Sacks et al., 2017). This is due to the well-established ability of saturated fat to raise LDL-C concentrations, increasing the risk of atherosclerosis. The American Heart Association Presidential Advisory states that RCTs that exchanged dietary saturated fat for polyunsaturated vegetable oil reduced the incidence of CVD by around 30%, which is a similar effect to statin treatment (Sacks et al., 2017). Reducing intake of saturated fat and replacing it with either monounsaturated fatty acids (MUFAs) or PUFAs may also positively affect insulin secretion and sensitivity (Charles-Messance et al., 2020).

There is increasing evidence however that different sources of SFAs may have different health effects. The Framingham Offspring study found that females who consumed the highest quintile of dairy derived SFAs had lower BMI and percentage fat mass and larger LDL-C particle sizes. Males who consumed in the highest quintile of dairy derived SFAs also had a less atherogenic risk profile (Yuan et al., 2022). This may be partly to do with the other components of dairy such as calcium, magnesium, vitamin D and potassium, which are associated with reduced cardiometabolic risk factors (Vissers et al., 2019). Coconut oil is one of the most common plant sources of SFAs, composed of 92% SFAs. Lauric acid is the main type of SFA in coconut oil, comprising 42%, and is known to raise LDL-C (Eyres, 2014).

Observational studies indicate that vegans generally eat less saturated fat than meat-eaters. A Belgian study comparing the nutritional quality of vegan, vegetarian, semi-vegetarians, pesco-vegetarians and omnivores found that vegans ate on average 21 g/day saturated fat, significantly lower than omnivores at 54 g/day (Clarys et al., 2014). A large meta-analysis of cross-sectional studies found that vegans consumed less total fat, saturated fat and mono-unsaturated fat, and more poly-unsaturated fat than omnivores (Benatar & Stewart, 2018).

2.6.2 Unsaturated Fats

Unsaturated fats have one or more double bonds, leading to their classification as monounsaturated or polyunsaturated fats. They are abundant in vegetable oils, nuts, seeds, and oily fish. MUFAs contain one double bond and can be synthesised by the body. PUFAs have two or more double bonds. The most common have a double bond at the sixth carbon from the omega (terminal) end and are called omega-6 (n-6). These are common in seed oils and high intakes are associated with a lower risk of CHD. PUFAs with a double bond at the third carbon from the omega end are known as omega-3 (n-3) fatty acids. The body cannot insert a double bond at the third or sixth carbon so n-3 and n-6 fatty acids must be obtained through the diet.

Alpha-linolenic acid (ALA) is the parent of the long chain n-3 PUFAs, and the main plant sources of this are legumes, walnuts, flaxseeds, and canola oil. ALA acts as a precursor for the essential long chain fatty acids EPA, DHA and docosapentaenoic acid (DPA) found mainly in oily fish. Wild fish consume EPA and DHA-containing marine algae and may have higher levels than farmed fish because of this. A small amount of EPA and then DHA can be synthesized from ALA but conversion is inefficient, between 0.2-8% of ALA to EPA, which may not be enough to satisfy physiological requirements (Mozaffarian & Wu, 2011). Trials using ALA-supplementation in humans have resulted in only small increases in EPA and DHA (Stark et al., 2016). High intakes of linoleic acid (LA), an omega-6 fatty acid found in vegetable oils, nuts, and seeds, can also limit conversion of ALA to EPA (Craig et al., 2021). Interestingly, conversion is higher in women than men, as the desaturase enzyme is regulated by insulin and female sex hormones (Djuricic & Calder, 2023; Mozaffarian & Wu, 2011). Conversion is also limited by lifestyle factors such as alcohol and caffeine consumption and cigarette smoking (Lane et al., 2014). Vegans commonly have much lower dietary plasma concentrations of EPA and DHA than fish-eaters, and lower dietary intakes of n-3 fatty acids than fish-eaters and omnivores (Lane et al., 2022; Sarter et al., 2015).

The omega-3 index measures the amount of DHA and EPA in the red blood cell membrane as a percentage of total fatty acids. A cardioprotective level has been estimated to be around 8%, and an index of <4% is associated with increased risk of CHD (Harris, 2007). As low intakes of DHA and EPA are independently associated with increased risk of death from CHD in epidemiological studies, the omega-3 index is used by some researchers as a predictor of risk for death from CHD (von Schacky, 2014). A study conducted on vegans with a low baseline omega-3 index concluded that microalgal DHA supplements are effective at raising plasma DHA and EPA concentrations and raising the omega-3 index to a satisfactory level (Sarter et al., 2015). A systematic review of algal DHA supplementation in vegetarians also concluded that algal DHA supplementation increased serum DHA concentrations and raised omega-3 indexes (Craddock et al., 2017). Microalgal DHA supplements are as effective as fish oil supplements at lowering TG, but are associated with a small increase in LDL-C of 0.23 mmol/L in persons without CHD . Like fish oil supplements, however, it increases the larger LDL-C particles, making the profile less atherogenic (Lane et al., 2022).

Omega-3 fatty acids have well-established benefits for cardiometabolic health, as well as visual and brain health (National Health and Medical Research Council, 2006). Sufficient intake of long-chain n-3 PUFAs is known to lower plasma TGs, reduce BP and resting heart rate, lower inflammation, and improve vascular function (Alexander et al., 2017; Mozaffarian

& Wu, 2011). Cross-sectional and prospective cohort studies report an inverse association between intakes of fatty fish or fish oil and morbidity and mortality from CVD (Djuricic & Calder, 2023). Although DHA does not reduce LDL-C, it seems to increase LDL-C particle size, making them less atherogenic (Djuricic & Calder, 2023).

2.6.3 Dietary Fibre

Dietary fibre (DF) is the indigestible component of plant foods, mostly composed of carbohydrate. It is resistant to digestion and absorption in the small intestine. Fermentation by bacteria in the large intestine releases metabolites such as short-chain fatty acids which have a wide range of beneficial effects on health. The composition of the microbiome can be altered significantly in a short time by diet. This has important implications for metabolic health as the microbiome has associations with the pathogenesis of atherosclerosis, T2D and obesity, among others (David et al., 2014; Singh et al., 2017). Sufficient DF intake is crucial for a well-functioning gut. Soluble fibre, such as that found in fruit and vegetables, forms a viscous gel with water, and insoluble fibre, found in whole grains, acts as a bulking agent.

Many epidemiological and clinical studies associate the intake of DF with a reduced risk of obesity, CVD and T2D (Haub & Lattimer, 2010). Individuals with the highest intakes of dietary fibre have generally have lower rates of hypertension, dyslipidaemia, obesity and T2D (Anderson et al., 2009). A longitudinal study of 1373 males found that for every 10 g increase in dietary fibre intake, coronary heart disease mortality was reduced by 17% (Streppel et al., 2008). Similarly, the EPIC study found a significant inverse relationship between dietary fibre intake and CVD mortality (Chuang et al., 2012). Soluble fibre influences serum TC and LDL-C through bile acid excretion and inhibition of de novo cholesterol synthesis (Anderson et al., 2009). Dietary fibre also has a bulking effect which contributes to a feeling of satiety, which may reduce food intake. Insoluble fibre, as the name suggests, does not dissolve in water, and helps promote regular laxation by speeding up the movement of food and waste through the body. Whole grains are rich sources of insoluble dietary fibre, and cereal fibre intake is associated with a reduced risk of T2D (Galisteo et al., 2008). As DF is an integral component of healthful foods such as fruit, vegetables, and wholegrains, it is difficult to distinguish its beneficial effects from the complete food package.

2.7 Summary

Although the current literature may have some mixed results, the overall picture indicates that vegan diets generally are beneficial for metabolic health, providing they are composed mostly of the healthful plant foods that confer cardiometabolic benefits. There is a paucity of research on the New Zealand vegan community, and therefore little is currently known about the metabolic health of New Zealand vegans. Research on the metabolic health of New Zealand vegans can help provide guidance to the vegan community on reducing their risk of diseases caused by poor metabolic health.

Many studies on the metabolic health of plant-based diets are focused on vegetarians, or those who occasionally eat animal products, and there are fewer studies that are solely restricted to vegans. Some of those studies that are restricted to vegans have inconsistent definitions of the term "vegan", most excluding all animal-derived foods, but some tolerating occasional intake of milk or eggs (Selinger et al., 2022a). Given the increasing popularity of vegan diets, it is important that robust research is conducted on the metabolic health effects of strict vegan diets.

Chapter 3: Research Study Manuscript

3.1 Abstract

Background: The popularity of a vegan diet is growing in New Zealand. Though there are potential nutrient deficiencies in a vegan diet, it is generally accepted that a vegan diet has greater metabolic benefits than a Western-style diet.

Objectives: This cross-sectional study aimed to explore the metabolic health status and dietary intake of adults who had been consuming a vegan diet for 2+ years.

Methods: Data were collected from The Vegan Health Research Programme. Participants completed questionnaires on demographic information, dietary practices and supplement use, and a four-day food diary. Participants gave a blood sample for analysis of HbA1c, total cholesterol, LDL-C, HDL-C, Chol/HDL ratio, triglycerides, and omega-3 index. Blood pressure, waist and hip circumference measurements were taken and body fat percentage was assessed using DXA.

Results: Participants (N=212) had a mean (SD) age of 39.5 (12.4) years and were predominantly female (73.1%). Mean (SD) metabolic health markers of HbA1c, total cholesterol, LDL-C, HDL-C, Chol/HDL ratio, triglycerides, diastolic blood pressure and waist circumference were all within normal ranges. Females had a normotensive mean (SD) systolic blood pressure of 114.2 (12.9) mmHg yet males were just above the low-risk normotensive category at 124.4 (12.0) mmHg. The mean (SD) omega-3 index result of 3.1 (1.2) placed most participants (86.3%) in the high-risk category for heart disease. Saturated fat intakes for males and females were 8.1% and 9.1% of energy, within the recommended range of 8-10% of energy. Dietary fibre intakes were high, at mean (SD) 55.0 (17.8) g/day for males and 43.4 (12.8) g/day for females.

Conclusion: This is the first New Zealand study to examine the metabolic health and dietary intake of adult vegans. The results of metabolic health markers indicate that the vegan diet may confer cardioprotective benefits. The low omega-3 index of most participants is concerning, and warrants longitudinal research to assess the level of risk conferred by a low omega-3 index result in a population with no other metabolic risk factors. Dietary intake data shows the population is consuming saturated fat within the recommended range and high amounts of dietary fibre, which may go some way towards explaining the metabolic health status of the participants.

Key words: vegan, metabolic health, cardiometabolic health, New Zealand

3.2 Introduction

A vegan diet is characterised by the elimination of all animal products from the diet. A vegan diet excludes meat, fish, dairy and eggs, and many vegans also exclude honey due to animal exploitation concerns. Animal protein is replaced with plant protein from soy, grains, legumes, pulses, nuts, and seeds. These foods, if eaten in conjunction with an abundance of vegetables and fruit, make a diet rich in fibre, vitamins, minerals, antioxidants, and unsaturated fatty acids. When compared to omnivorous diets, vegan diets often have lower energy and saturated fat intake, and a higher intake of dietary fibre (Benatar & Stewart, 2018; Craig, 2009). A healthy vegan dietary pattern is known to have beneficial effects on long-term metabolic health (Herpich et al., 2022). The wide range of plant foods, and thus fibre, eaten on a healthy vegan diet has beneficial effects for the gut microbiota, resulting in production of short-chain fatty acids. These bacterial postbiotics nourish the intestinal cells and the wide variety of fibre results in a diverse microbiome with anti-inflammatory effects, resulting in improved glucose tolerance and lipid metabolism (Glick-Bauer & Ming-Chin, 2014).

Vegan diets can vary widely in their composition of macronutrients and energy intake, therefore planning and individual nutrition advice are advisable to ensure a healthful diet. The position of the American Dietetic Association is that a well-planned vegan diet is appropriate for all stages of the life cycle, including pregnancy and lactation (Craig & Mangels, 2009). Due to the exclusion of animal products, a vegan diet that is not carefully planned or appropriately supplemented risks deficiencies in several vitamins and minerals, especially iron, calcium, zinc, omega-3 fatty acids and vitamins D and B12 (Craig, 2009). These deficiencies can affect bone and brain health (Craig, 2009). There is growing interest worldwide and in New Zealand in a switch to a vegan diet for purposes of health, environmental sustainability, and animal welfare. Data analysed from the 2018 NZ Attitudes and Values study showed that 1.1% of New Zealanders followed a vegan diet (Milfont et al., 2021). Little is currently known about the dietary intake of the New Zealand vegan population, and the effect the diet is having on their health. This research paper will fill the gaps in the knowledge of the metabolic health and dietary intake of the New Zealand vegan population and help inform dietary advice for this population to ensure they are eating an optimal diet and reducing their risk of developing metabolic diseases.

New Zealand, like most of the Western world, is dealing with increasing rates of non-communicable diseases. Our Western diet and sedentary lifestyles are partly to blame for the increasing rates of obesity, type 2 diabetes (T2D), and cardiovascular disease (CVD). A recent World Health Organization report on the impact of plant-based diets on health, sustainability, and the environment notes that the foods that have the worst environmental impacts, which are red and processed meat, also have the highest disease risk. The report notes that healthful plant-based diets (though not strictly vegan) should be recommended as a strategy to prevent and control non-communicable diseases (WHO, 2021).

Blood lipid concentrations, blood pressure, waist-hip ratio, waist circumference, body mass index, body fat percentage and HbA1c levels are all important indicators of metabolic health status, as less than optimal levels of these markers all contribute to the risk of developing T2D and CVD. Though there are genetic, socioeconomic, and environmental factors that contribute to these metabolic health markers, a person’s dietary intake has an impact on these metabolic markers.

Research into the metabolic health effects of vegan diets indicates there are many metabolic benefits. A traditional vegan dietary pattern, with a diverse amount of plant foods, may also promote a more diverse and stable microbiome, resulting in reduced risk of metabolic diseases. The microbiome of vegans is distinctly different to omnivores and is rich in species protective against metabolic disease. This has the effect of reducing inflammation and improving glucose tolerance and lipid metabolism (Glick-Bauer & Ming-Chin, 2014). Vegan diets are generally beneficial for reducing total and LDL-C, due to the high amounts of soluble fibre from plant foods and a lower intake of saturated fat due to the exclusion of red meat (Ferdowsian & Barnard, 2009; Hartley et al., 2016). There is conflicting evidence regarding the effects of a vegan diet on blood pressure (BP). Many studies report a decrease in BP on a vegan diet, or no difference between vegans and omnivores in observational studies (Benatar & Stewart, 2018; Termannsen et al., 2022). Other studies report reductions in BP for vegan dietary interventions, and lower BP for vegan participants in observational studies (Appleby et al., 2002; Lee et al., 2020). The reason for the mixed results is not clear, but it may be related to the composition of the vegan and omnivorous diets being studied. Vegan diets also appear to be beneficial for blood glucose homeostasis and those on a vegan diet are less likely to develop T2D (Pollakova et al., 2021). Obesity rates are increasing in New Zealand and across the world, and obesity is a risk factor for many metabolic diseases. Observational studies consistently report that vegans have a lower BMI than omnivores, pescatarians and vegetarians (Davey et al., 2003; Dinu et al., 2017).

There is limited knowledge currently on the metabolic health and dietary intake of the New Zealand vegan population. The aim of this paper is to explore the metabolic health and dietary intake of the New Zealand vegan population.

3.3 Methods

3.3.1 Study Design

This study used data collected by the Vegan Health Research Programme to report on the metabolic health and dietary intake of New Zealand vegans. Ethical approval was granted by the Health and Disability Ethics Committee (HDEC 2022 EXP 12312). The study was funded by the Lottery Health Project Grant (LHR-2022-185693).

3.3.2 Participants and Recruitment

Recruitment took place in Auckland, New Zealand, between July 2022 and March 2023. Participants were recruited through advertising on vegan Facebook groups, community Facebook groups, through flyers distributed to vegan cafes and grocery stores across Auckland, and by word of mouth. Applicants were screened to confirm eligibility. Criteria for participation were that participants must be aged 18 years or over, must not be pregnant or have any likelihood of becoming pregnant, and must have followed a vegan diet for two years or more.

3.3.3 Study Procedures and Data Collection

Once screened, participants were sent a four-day food diary form with instructions on how to complete the food diary correctly, a consent form to sign, and a demographic questionnaire to complete. Participants were invited to the Massey University Nutrition Research Facility in Albany, Auckland, New Zealand, to deliver their signed consent forms and food diaries, have their questionnaires checked and receive a $20 gift voucher. If participants had not completed the questionnaires prior to the visit, they were assisted to complete it at the visit by a trained researcher.

Participants were required to abstain from exercise and consumption of caffeinated drinks for two hours prior to the visit. While on site the participants’ body composition and anthropometrics were measured. Weight, height, waist, and hip circumference were measured by a researcher. A trained operator performed a Dual X-Ray Absorptiometry (DXA) (Hologic QDR series Horizon, Wisconsin, MA, USA) scan of proximal hip, lumbar spine, and whole body. Blood pressure was measured using an Omron Digital Automatic Blood Pressure Monitor (Model HEM-907, Omron Healthcare Ltd, Japan) electronic blood pressure meter. Three separate measurements were taken with one-minute rest intervals in between and an average reading recorded. Participants were seated and rested for five minutes before measurements were taken.

A qualified phlebotomist took a non-fasted venous blood sample from participants. Three drops were pipetted from each venous sample. One drop was used for on-site assessment of haemoglobin using HemoCue Hb 201+ (Hemocue AB, Sweden), another drop was used for on-site assessment of lipids using either Afinion 2 (Abbott, Sweden) or Cobas b101 analyser (Roche, Japan). The third drop was applied to special paper and sent to the OmegaQuant laboratory in South Dakota, USA, where it was analysed for red cell fatty acids including long-chain Omega-3 and Omega-6 PUFAs, and determination of Omega-3 index.

3.3.4 Food Diary Analysis

The four-day food diary was entered into FoodWorks10 software (Xyris Software, Sydney, Australia) by trained researchers using standardised procedures. Entries were checked for accuracy by another researcher and intake of energy, micronutrients and macronutrients was assessed. Intake was compared against the Estimated Average Requirement (EAR), Adequate Intake (AI) recommended for New Zealand adults, or the suggested dietary target to reduce chronic disease risk (SDT) (National Health and Medical Research Council, 2006). Percentage of energy contributed by the three macronutrients, protein, fat, and carbohydrate, was calculated using Atwater factors (17 kJ per gram of protein and carbohydrate, 36 kJ per gram of fat) and compared against the acceptable macronutrient distribution range (AMDR) (National Health and Medical Research Council, 2006).

3.3.5 Data and Statistical Analysis

Statistical analysis was conducted using SPSS Statistics, version 27.0, SPSS Inc., Chicago, IL. Data were treated as normal based on the central limit theorem, in which a sample size larger than 30 is assumed to be normally distributed (Vrbin, 2022). The population was described using mean ± standard deviation (SD). The percentage of demographic characteristics was calculated. The relationship between dietary intake and metabolic health biomarkers was explored using multivariate linear regression. This controlled for the following variables that may have impacted results, such as age, sex, body fat percentage and energy intake. A *P*-value <0.05 was considered statistically significant. If any participants had missing data that was an independent variable (for example serum blood sample), they were still included in any analyses not involving the missing variable.

3.4 Results

3.4.1 Participants

In total, 212 adults participated in the Vegan Health Research Programme and provided dietary data, serum blood samples and completed questionnaires. The demographic characteristics of the participants are shown in Table 1. The mean age of participants was 39.4 years and age ranged from 19 to 75 years. Participants were predominantly female (n=155). Two participants identified as gender diverse, but for the purpose of statistical analysis were reclassified into their biological sex. Most participants identified as being of European ethnicity (85%), and many had a Bachelor's Degree or higher (68.2%).

Table 3.1

Participant Characteristics

	Total (N=212)	**Male (n=57)**	**Female (n=155)**	***P*-value[2]**
Age (years) [1]	39.4 (12.4)	40.1 (12.1)	39.2 (12.6)	0.55
Ethnicity ‡[3]				
NZ European	178 (85%)	50 (88%)	128 (84%)	
Māori	8 (3.8%)	0 (0%)	8 (5.2%)	
Pacific Peoples	1 (0.5%)	1 (1.8%)	0 (0%)	
Asian	16 (7.6%)	3 (5.3%)	13 (8.5%)	
Middle Eastern/Latin American/African	7 (3.3%)	3 (5.3%)	4 (2.6%)	
Highest level of education‡[3]				
High school or lower	21 (9.9%)	8 (13.8%)	13 (8.4%)	
Diploma/certificate	45 (21%)	18 (32%)	27 (17%)	
University degree	146 (68.2%)	31 (54%)	115 (73.5%)	
Length of time vegan[3]				0.51
2-4 years	84 (40%)	22 (39%)	62 (40%)	
5-10 years	93 (44%)	28 (49%)	65 (42%)	
10+ years	35 (17%)	7 (12%)	28 (18%)	
Physical activity[3]				0.059[4]
Low	35 (17%)	8 (15%)	27 (18%)	
Moderate	158 (76%)	38 (70%)	120 (78%)	
High	15 (7.2%)	8 (15%)	7 (4.5%)	

Note. [1] Mean (SD)

[2]Wilcoxon rank sum test

[3] n (%)

[4]Fisher's exact test

‡ The following data is missing: ethnicity n=2, highest level of education n=45, physical activity n=4

3.4.2 Metabolic Biomarkers

The mean metabolic biomarker levels were all below the threshold for disease risk for males and females (Table 3.2). HbA1c ranged from 24-53 mmol/mol, and three participants had HbA1c values ≥41 mmol/mol. Total cholesterol (TC) ranged from 2.6-8.4 mmol/L, and 54 participants had TC ≥5.0 mmol/L. LDL-C ranged from 0.1-5.6 mmol/L, and 12 participants had LDL-C ≥3.4 mmol/L. HDL-C ranged from 0.8-2.9 mmol/L, and two participants had HDL-C <1.0 mmol/L. TG ranged from 0.5-5.8 mmol/L, and 26 participants had a TG level >2.0 mmol/L. Chol/HDL ratio ranged from 1.4-6.4, and 8 participants had a Chol/HDL ratio >4.5. Males had higher concentrations than females for all biomarkers except HDL-C, for which males had a lower serum concentration. There were significant differences between males and females for HDL-C, TG and Chol/HDL (P<0.001).

Table 3.2

Metabolic Biomarkers

	Total (N=212)	**Male (n=57)**	**Female (n=155)**	***P*-value²**	**Reference ranges³**
HbA1c (mmol/mol)¹	32.2 (3.5)	32.5 (4.0)	32.0 (3.2)	0.62	<41
Total cholesterol (mmol/L)¹	4.5 (1.0)	4.6 (1.1)	4.5 (0.9)	0.62	<5.0
LDL-C (mmol/L)¹	2.1 (0.8)	2.3 (1.0)	2.0 (0.7)	0.070	<3.4
HDL-C (mmol/L)¹	1.8 (0.4)	1.5 (0.3)	1.9 (0.4)	**<0.001**	>1.0
Triglycerides (mmol/L)¹	1.4 (0.7)	1.7 (1.0)	1.2 (0.6)	**<0.001**	<2.0
Chol/HDL ratio¹	2.7 (0.8)	3.2 (1.0)	2.5 (0.6)	**<0.001**	<4.5

Note. ¹ Mean (SD)

² Wilcoxon rank sum test

³(Mansour, 2023)

3.4.3 Omega-3 Index

The majority (86.3%) of the 199 participants that submitted blood spots for analysis were in the high-risk category for heart disease by having a low omega-3 index result (<4%) (Table 3.3). Forty-four participants (20.8%) reported taking an omega-3 supplement regularly. There was no significant difference between the omega-3 index results for males and females.

Table 3.3

Omega-3 Index Blood Spot Results

	Total (N=212)	Male (n=57)	Female (n=155)	*P*<value[3]
Omega-3 Index[1]	3.2 (0.7)	3.0 (0.7)	3.2 (0.7)	0.069
High risk (<4%)[2]	183 (86.3%)	50 (87.7%)	132 (85.2%)	
Intermediate risk (4-8%)[2]	16 (7.5%)	2 (3.4%)	14 (9.1%)	
Low risk (>8%)[2]	0 (0%)	0 (0%)	0 (0%)	
Missing	13 (6.1%)	4 (6.9%)	9 (5.8%)	

Note. [1] Mean (SD)

[2] n (%)

[3] Wilcoxon rank sum test

3.4.4 Dietary Intake

Protein intake for males and females was above the EAR of 52-65 g/day and 37-46 g/day respectively. However protein intake for both groups was just below the AMDR of 15-25% of daily energy intake (Table 3.4). The range of protein intake varied from 24.5-185.3 g/day. Total fat intake was high, with males just under the upper end and females just exceeding the AMDR of 20-35% of total energy, and ranged from 13.4-192.7 g/day. Saturated fat intakes fell within the AMDR of a maximum of 8-10% of total energy, and varied widely with a range from 4.0-65.9 g/day. PUFA intakes were a mean (SD) 28.7 (9.1) g/day for males and 20.9 (7.9) g/day for females. PUFA intake analysis cannot be broken down further into LA, ALA and n-3 LC fatty acids, but intake of this population is likely exceeding the AIs of 13 g/day LA and 1.3 g/day ALA for males, and 8 g/day LA and 0.8 g/day ALA for females. Mean dietary fibre intake surpassed the AI of 30 g/day for males and 20 g/day for females, and also exceeded the SDT of 38 g/day and 28 g/day for males and females. Dietary fibre intake varied widely with a range from 10.9 g/day to 133.9 g/day. Carbohydrate intake for females was just below the AMDR of 45-65% of intake and males just over the lower end of the range. Carbohydrate intake ranged from 83.3-654.7 g/day. Vitamin A intakes were above the EARs (males 625 µg, females 500 µg) for both groups and below the SDT (males 900 µg, females 700 µg). Vitamin C intakes were above the EARs (males and females 30 mg) for both groups and below the SDT (males 220 mg, females 190 mg). Mean vitamin E intake was above the AI (males 10 mg, females 7 mg) and SDT (males 19 mg, females 14 mg) for both groups. Males had significantly higher intakes than females of energy, protein, total fat, saturated fat, MUFA, PUFA, carbohydrates, dietary fibre, and vitamin E.

Table 3.4

Dietary Intake

	Total (N=212)	Male (n=57)	Female (n=155)	*P*-value[3]	Recommended intake[4]
Energy (kj)[1]	9,077.4 (2,519.3)	11, 304.6 (2,652.4)	8, 256.0 (1,902.5)	**<0.001**	BMR x PAL[5]
Protein (g)[1]	77.2 (27.8)	99.4 (33.4)	69.1 (20.1)	**<0.001**	EAR males: 52-65 g/day EAR females:37 – 46 g/day
-% of energy[2]	14.5 (5.2)	14.9 (5.0)	14.2 (4.1)		15-25% of energy
Total fat (g)[1]	86.9 (33.1)	105.0 (33.0)	80.2 (30.7)	**<0.001**	
-% of energy[2]	35.4 (13.5)	34.4 (10.8)	35.9 (13.8)		20-35% of energy
SFA (g)[1]	21.5 (10.3)	24.9 (10.5)	20.2 (9.9)	**<0.001**	
-% of energy[2]	8.8 (4.2)	8.1 (3.4)	9.1 (4.4)		8-10% of energy
MUFA (g)[1]	35.7 (15.5)	43.9 (17.2)	32.7 (13.7)	**<0.001**	
-% of energy[2]	14.6 (6.3)	14.4 (5.6)	14.7 (6.1)		
PUFA (g)[1]	23.0 (9.0)	28.7 (9.1)	20.9 (7.9)	**<0.001**	
-% of energy[2]	9.4 (3.7)	9.4 (3.0)	9.4 (3.5)		
CHO (g)[1]	241.4 (77.3)	306.9 (89.9)	217.3 (55.4)	**<0.001**	
-% of energy[2]	45.2 (14.5)	46.2 (13.5)	44.7 (11.4)		45-65% of energy
Added sugars (g)[1]	28.9 (19.3)	33.4 (20.0)	27.3 (18.9)	**0.037**	
Dietary fibre (g)[1]	46.6 (15.1)	55.0 (17.8)	43.4 (12.8)	**<0.001**	AI males: 30g/day AI females: 25 g/day
Total Vit A eq. (µg)[1]	1,048.9 (738.4)	1,035.85 (614.4)	1,053.7 (781.1)	0.78	EAR males: 625 µg/day EAR females: 500 µg/day
Vit C (mg)[1]	144.6 (96.9)	147.5 (77.3)	143.5 (103.5)	0.29	EAR males and females: 30 mg/day
Vit E (mg)[1]	20.6 (10.6)	22.7 (8.8)	19.8 (11.1)	**0.005**	AI males 10 mg/day, females 7 mg/day
Missing	19	5	14		

Note. [1] Mean (SD)

[2] Mean (SD) percentage of energy calculated using Atwater factors of 17 kJ per gram of protein and carbohydrate, and 37 kJ per gram of protein

[3] Wilcoxon rank sum test

[4](National Health and Medical Research Council, 2006)

[5]BMR = basal metabolic rate, PAL = physical activity level

3.4.5 Anthropometry and Blood Pressure

The mean body mass index (BMI) was within the normal range for males and females (Table 3.5). Waist circumference was in the lower-risk category for males and females. Mean systolic blood pressure (BP) for males was above the low-risk normotensive category at 124.4 (12.0) mmHg, but females had a mean (SD) BP of 114.2 (12.9) mmHg, placing them in the low-risk category. Diastolic BP for males and females was both in the low-risk normotensive category at mean (SD) 75.0 (9.4) mmHg for males and 71.8 (9.2) mmHg for females. Waist-hip ratio was just in the increased-risk category for males but below the cut-off for females. Many more females (71%) than males (5.3%) had a body fat percentage >30%. The mean female BMI and body fat percentage fit the “normal weight obesity” profile of a normal BMI and body fat >30% (Oliveros et al., 2014). There were significant differences between males and females for weight, height, waist circumference, body fat percentage and systolic and diastolic blood pressure (Table 3.5).

Table 3.5

Anthropometry and Blood Pressure

	Total (N=212)	Male (n=57)	Female (n=155)	*P*-value[2]	Reference ranges – low risk
Weight (kg)[1]	69.3 (12.4)	79.0 (12.4)	65.8 (10.3)	**<0.001**	
Height (cm)[1]	169.9 (9.0)	179.4 (7.7)	166.4 (6.7)	**<0.001**	
BMI (kg/m²) [1]	23.9 (3.1)	24.5 (3.0)	23.7 (3.2)	0.080	18.5-24.9[3]
Waist circumference (cm)[1]	81.8 (10.6)	87.5 (8.6)	79.7 (10.5)	**<0.001**	Males <94 Females <80[3]
Systolic BP (mmHg)[1]	117.0 (13.4)	124.4 (12.0)	114.2 (12.9)	**<0.001**	<120[4]
Diastolic BP (mmHg)[1]	72.7 (9.3)	75.0 (9.4)	71.8 (9.2)	**0.014**	<80[4]
Waist-hip ratio	0.84	0.90	0.82		Males <90 Females <0.85[3]
Body fat %[1]	30.5 (7.4)	22.7 (5.0)	33.3 (6.0)	**<0.001**	Males <25 Females <30[5]

Note. [1] Mean (SD)

[2] Wilcoxon rank sum test

[3] (World Health Organization, 2008)

[4] (Joint National Committee on Prevention, 1997)

[5] (Okorodudu et al., 2010)

3.4.6 Relationship Between Participant Characteristics, Dietary Intake, and Metabolic Biomarkers

Multivariate linear regression was used to determine if age, sex, education, physical activity, body fat percentage (*z*-score), saturated fat intake (percentage of energy intake) and dietary fibre intake (grams per kilojoule of energy) influenced metabolic biomarkers. Increasing age was associated with increased HbA1c (beta = 0.082, *P*<0.001), total cholesterol (beta = 0.038, *P*<0.001), LDL-C (beta = 0.028, *P*<0.001), triglycerides (beta = 0.017, *P*<0.001), and Chol/HDL ratio (beta = 0.017, *P*<0.001). Increasing body fat percentage (*z*-score) was associated with increased total cholesterol (beta = 0.212, *P*<0.002), LDL-C (beta = 0.211, *P*<0.001), Chol/HDL ratio (beta = 0.258, *P*<0.001) and decreased HDL-C (beta = -0.067, *P* = 0.021). Female sex had a negative association with LDL-C (beta = -0.246, *P* = 0.035), triglycerides (beta = -0.455, *P*<0.001), Chol/HDL ratio (beta = -0.675, *P*<0.001) and a positive association with HDL-C (beta = 0.356, *P*<0.001). Saturated fat intake (as a percentage of total energy intake) and dietary fibre intake (grams of dietary fibre per kilojoule of energy), education and physical activity had no association with metabolic biomarkers.

3.4.7 Relationship Between Participant Characteristics and Omega-3 Index

There was no association found between age, sex, education, physical activity, PUFA intake (% total energy) or body fat percentage (*z*-score) and omega-3 index. There was a positive association between omega-3 supplement use and omega-3 index result (beta 0.669, $P<0.001$).

3.4.8 Relationship Between Participant Characteristics, Dietary Intake, Anthropometry and Blood Pressure

Multivariate linear regression was used to look for associations between age, sex, education, physical activity, body fat percentage (*z*-score), saturated fat intake (percentage of total energy) and dietary fibre intake (grams per kilojoule of energy) and anthropometrical markers. Increasing age was associated with an increase in all the anthropometrical markers: waist circumference (beta = 0.157, $P = 0.004$), systolic blood pressure (beta = 0.389, $P<0.001$), diastolic blood pressure (beta = 0.205, $P<0.001$), and body fat percentage (beta = 0.201, $P<0.001$). Female sex had a negative association with waist circumference (beta = -7.253, P<0.001), and systolic blood pressure (beta = -8.982, $P<0.001$), yet a positive association with body fat percentage (beta = 11.306, $P<0.001$). Increasing body fat percentage (*z*-score) was associated with increased waist circumference (beta = 5.484, $P<0.001$), diastolic blood pressure (beta = 2.109, $P=0.003$). Lower protein intake (as a percentage of energy) had a small association with increased body fat percentage (beta = -0.265, $P = 0.008$). Increased saturated fat intake (as a percentage of energy) had a small negative association with systolic blood pressure (beta = - 0.709, $P = 0.029$) and diastolic blood pressure (beta = -0.524, $P = 0.030$).

3.5 Discussion

This study shows that most of the New Zealand vegans participating have good metabolic health according to the biomarkers and anthropometry assessed in this study. The positive results of most metabolic health markers indicate that the vegan diet may confer cardioprotective benefits.

3.5.1 Metabolic Biomarkers

In this study, the mean metabolic biomarkers of HbA1c, total cholesterol, LDL-C, HDL-C, triglycerides, and Chol/HDL ratio were all below the threshold for disease risk. The majority (73.8%) of participants had total cholesterol below 5 mmol/L and LDL-C (93.8%) below 3.4 mmol/L. Research indicates that those on a vegan diet are likely to have lower TC and LDL-C levels than the omnivorous population (Koch et al., 2023; Selinger et al., 2022a). Though this study does not have a comparable omnivorous population, the mean TC and LDL-C results of the participants are within normal ranges. Only three participants (1.4%) had HbA1c levels ≥41 mmol/mol, indicating pre-diabetes, which implies that most participants currently have low risk of T2D. This is in accordance with the literature that a vegan diet may have a beneficial effect on HbA1c (Selinger et al., 2022a; Termannsen et al., 2022).

3.5.2 Omega-3 Index

None of the participants in this study were in the low-risk category for heart disease as classified by the omega-3 index (>8%), and the majority (86.3%) were in the high-risk category (<4%). This may be because only 44 participants reported regularly taking an omega-3 supplement, which has been shown to raise omega-3 index. One clinical trial supplemented vegans (n = 46) with a vegetarian omega-3 supplement for 4 months, after which time their omega-3 index rose from 3.1 (0.6)% to 4.8 (0.8)% (*P* = <0.009) (Sarter et al., 2015). It is still unknown whether the risk of low omega-3 index in vegans translates into the same CVD risk that applies to omnivores, given vegans already have lower CVD risk than omnivores. A meta-analysis of studies conducted on omnivores found a 6% reduction in risk of CHD in RCTs, and an 18% reduced risk of CHD in prospective cohort studies with greater DHA and EPA intake from food or supplements. Greater risk reduction was achieved with increased DHA and EPA intake in populations that already had elevated triglycerides and LDL-C (Alexander et al., 2017). Supplementation with algal DHA and increasing the omega-3 index in vegans is assumed to optimise their cardiac protection, but there are as yet no large-scale longitudinal studies that can quantify the reduction in risk (Craddock et al., 2017; Craddock et al., 2022). The omega-3 index cannot yet be widely used in clinical medicine due to inconsistencies in measurements between laboratories. There are also inconsistencies in measurements of red blood cell fatty acids between studies, with some using the red blood cells and others measuring plasma or whole blood concentrations of fatty acids, so results cannot be directly compared (Harris et al., 2017). It would be beneficial to explore CVD outcomes in longitudinal studies with vegans to understand whether their generally better CVD risk profile offsets their lower omega-3 index. At present we do not know whether vegans with higher omega-3 index have substantially lower risk of CVD than vegans with lower omega-3 index.

3.5.3 Dietary Intake

The dietary intake of the vegan participants in this study differed slightly from the consensus in the literature. In contrast to much of the literature that classifies a vegan diet as a low-fat, high-carbohydrate diet, this population had a higher intake of fat (35.4% total energy) and a lower intake of carbohydrates (45.2% total energy) (Bakaloudi et al., 2021; Davey et al., 2003; Pollakova et al., 2021). Saturated fat intakes were 8.1% of energy for males and 9.1% for females. The EPIC-Oxford study found vegans had a mean saturated fat intake of 5% of energy, which was around half the mean intake of meat-eaters, who consumed 10.7% of energy from saturated fat (Davey et al., 2003). Other studies, including a systematic review and meta-analysis, have also found that vegan diets have lower consumption of saturated fats than omnivores (Bakaloudi et al., 2021; Clarys et al., 2014). This vegan population had a higher percentage of energy from PUFAs (9.4% of total energy) than the EPIC-Oxford cohort, who were consuming 7.53 (2.91)% (Davey et al., 2003).

The wide range of protein intake in this study, from 24-185 g/day, indicates that some vegans are not consuming adequate protein, and some may be overconsuming protein. Mean protein intake was 14.5% of energy, which was higher than the EPIC-Oxford cohort at 12.9 (2.16)% total energy (Davey et al., 2003). Dietary fibre intake was high in this population, a mean (SD) 55.0 (17.79) g/day for males and 43.4 (12.72) g/day for females. These findings were in accordance with the literature which consistently finds that vegans have a higher fibre intake than omnivores (Bakaloudi et al., 2021). High-fibre diets are indicative of a diet rich in fruit, vegetables, and wholegrains, which are associated with many benefits for metabolic health, including reduced risk of T2D, reduced BMI and an improved lipid profile (Craig et al., 2021; Glick-Bauer & Ming-Chin, 2014). It is interesting to note the wide ranges of intakes from the four-day food records, especially saturated fat (4.0-65.9 g/day), protein (24.5-185.3 g/day) and dietary fibre (10.9-133.9 g/day). This indicates different vegan dietary patterns which could be explored further in relation to metabolic health.

3.5.4 Anthropometry and Blood Pressure

The high percentage of body fat in the female participants is a concern. Excess body fat, regardless of weight, is associated with metabolic dysregulation even in those in a normal weight range (Okorodudu et al., 2010). It would be informative to stratify the participants into those in the "normal weight obesity" range and ascertain if they were more likely to suffer metabolic dysregulation than participants with a normal BMI and a lower percentage body fat. Most other markers were within normal ranges, except for systolic blood pressure and waist-hip ratio for males, for which the mean results were above normal ranges.

BMI was within the normal range for females and males. This is in accordance with the literature that states that vegans generally have lower BMI than omnivores (Davey et al., 2003; Orlich & Fraser, 2014). Many observational studies also report a lower systolic and diastolic BP in vegans compared to omnivores, though randomised controlled trials do not consistently find vegan diets to lower blood pressure in participants (Appleby et al., 2002; Lopez et al., 2019).

3.5.5 Relationships Between Participant Characteristics, Dietary Intake, and Markers of Metabolic Health

Though these participants had a high mean intake of dietary fibre, linear regression analysis found no association between dietary fibre intake and total cholesterol, LDL-C, HDL-C, triglycerides, or Chol/HDL ratio. Though the literature points to the high levels of dietary fibre in a vegan diet as one of the most probable reasons for vegans' generally lower HbA1c levels, our analysis found no association between dietary fibre intake and HbA1c (Pollakova et al., 2021). This may be due to the fact that most (98.6%) of the participants had HbA1c in the normal range, <41 mmol/mol. Vegans' generally lower BMI is often cited in the literature as another reason for their lower risk of diabetes, yet analysis found no association between body fat percentage or BMI and HbA1c (Berkow & Barrnard, 2006). Age was the only predictor that had a positive association with HbA1c. While LDL-C, HDL-C, triglycerides, Chol/HDL ratio and HbA1c are partly influenced by lifestyle and genetics, they are also influenced by diet and therefore provide an insight into some of the health effects of a vegan diet.

Our analysis found no association between body fat percentage, age, sex, education, physical activity or PUFA intake (percentage of energy intake) and omega-3 index results. The only variable that affected omega-3 index levels was omega-3 supplementation. This is encouraging as it indicates that supplementation by the vegan population may improve omega-3 index.

There was a small negative association between protein intake (as a percentage of total energy) and body fat percentage in this study, independent of sex and age. The effect of a protein intake below the AMDR is an important direction for future research based on this dietary intake data. Plant protein is called “incomplete protein” as plant sources of protein, apart from soy, do not contain all the essential amino acids required by the human body in sufficient quantities. The Protein Digestibility Corrected Amino Acid Score (PDCAAS) indicates the amino acid composition and digestibility of proteins, and a score of 100% indicates the protein meets the body’s amino acid requirements. Milk and egg have scores of 100%, and soy protein isolate is the only plant protein with a score of 100% (Insaf et al., 2019). By combining different plant proteins those on a vegan diet can obtain all the essential amino acids but the quantity may not be enough for all the necessary functions including muscle synthesis, especially in those with increased nutrient needs such as pregnant women and those who are ill. Many studies report that animal protein is more efficiently used for muscle synthesis than plant protein (Insaf et al., 2019).

It was surprising that an association was found between increased saturated fat consumption and decreased systolic BP and diastolic BP, however this effect was small and not clinically meaningful. It appears that coconut oil was the main source of saturated fat in the four-day food records. Most studies on the effects of coconut oil on cardiometabolic markers are restricted to plasma lipids, due to the high saturated fat content and it’s known ability to raise LDL-C. A systematic review and meta-analysis that included studies on blood pressure found an increase in systolic and diastolic BP when coconut oil was used instead of placebo oils, and an increase in diastolic BP only when coconut was compared with olive oil (Duarte et al., 2022).

3.5.6 Strengths and Limitations

A strength of this study is the large sample size and wide age range, which gives a clearer picture of the metabolic health of New Zealand vegans. There are several demographic factors that limit the generalisability of our results. The vegan cohort were only recruited from Auckland, due to the necessity to travel to Massey University, and most of the participants were NZ European. Socio-economic characteristics can also be a confounding factor, as socio-economic factors have a large role in health outcomes, yet participant socio-economic information was not recorded apart from level of education. The cohort was mostly highly educated and contained fewer males than females.

3.5.7 Conclusion

This is the first New Zealand study to examine the metabolic health and dietary intake of adult vegans. The positive results of most metabolic health markers indicate that the vegan diet may confer cardioprotective benefits. The low omega-3 index of most participants is concerning, and warrants longitudinal research to assess the level of risk conferred by a low omega-3 index result in a population with no other cardiometabolic risk factors. However, the positive association between omega-3 supplement use and a higher omega-3 index result indicates that the vegan population respond well to supplementation. The findings of the present study may help guide the growing New Zealand vegan community towards a nutritionally optimal vegan diet.

Chapter 4: Conclusions and Recommendations

4.1 Achievement of Aims and Objectives

The overall aim of this study was to explore the metabolic health status and dietary intake of New Zealand vegans. Firstly, this study found that vegans in New Zealand have generally good metabolic health, with mean metabolic markers of diastolic blood pressure, BMI, waist circumference, HbA1c, total cholesterol, LDL-C, HDL-C, Chol/HDL ratio, and triglycerides all below the thresholds for disease risk. Secondly, this study found that vegans in New Zealand have a mean macronutrient distribution of 14.5% protein, 35.4% fat, and 45.2% carbohydrates per day. When compared to the AMDR (total fat 20-35%, carbohydrate 45-65% and protein 15-25%), vegans were eating just below the lower end of the range for protein, at the top of the range for fat and at the lower end of the range for carbohydrates. When looking at specific nutrients that may affect metabolic health, intake of saturated fat was a mean 21.5 g/day, which is 8.8% of total energy. This is within the recommended range for saturated fat of 8-10% of total energy. With regards to dietary fibre, both males (55.0 g/day) and females (43.4 g/day) were consuming far above the SDTs to reduce chronic disease risk of 38 g/day for males and 28 g/day for females. However, there were wide ranges of intake, with the intake of saturated fat ranging from 4.0 to 65.9 g/day, and dietary fibre ranging from 10.9 to 133.9 g/day. These ranges indicate different dietary patterns which may have differing health effects. Additionally, this study found little association between metabolic health and dietary intake, with only small associations found between saturated fat and systolic and diastolic blood pressure, and protein, dietary fibre, and body fat percentage. None of the associations found were large enough to be clinically meaningful.

The study also found that the mean female body fat percentage of 33.3% and BMI of 23.7 kg/m^2 fit the "normal weight obesity" profile, which has been linked to higher risk of CVD (Oliveros et al., 2014). Regardless of body weight, a body fat percentage over 30% has been found to carry higher risk for metabolic diseases (Okorodudu et al., 2010). However, the mean female waist circumference was just under the cut-off for increased metabolic risk, indicating this population did not display central obesity. Longitudinal studies on vegans may give some indication of the CVD risk level of carrying excess body fat with a normal body weight.

To our knowledge, this is the first study to investigate the omega-3 status of New Zealand vegans. Studies in vegans overseas have shown that vegans, due to their avoidance of fish, typically have lower omega-3 index results than those who eat fish (Craddock et al., 2022; Sarter et al., 2015). The study found that most (86%) of the population had omega-3 index results <4%, placing them at high risk of CVD. There was a positive association found between omega-3 supplement use and a higher omega-3 index result, indicating that supplementation may improve omega-3 index result. This has been shown in a RCT which tested vegans at baseline and then re-tested after four months' supplementation with a vegetarian omega-3 supplement containing 254 mg DHA and EPA. Participants' omega-3 levels increased from mean (SD) 3.1 (0.6) % to 4.8 (0.8) % (P = 0.009) (Sarter et al., 2015).

4.2 Research Impact

This is the first study to investigate the metabolic health and dietary intake of NZ vegans. With the growing popularity of vegan diets and the growing rates of metabolic diseases it is timely to look at the health effects of the vegan diet. The results of most metabolic health markers indicate that the vegan diet may confer cardioprotective benefits. The finding that most of the population had a low omega-3 index result may be useful in guiding public health advice, and the vegan population may wish to consider omega-3 supplementation. Nutrition education to this population may be beneficial. Yet the results of this study should be interpreted with caution, as the highly educated and mostly NZ European population are less likely to have poor metabolic health due to a higher socioeconomic status. Thus, the results may not be generalisable to other populations.

4.3 Strengths

This study had several strengths. Firstly, the sample size was large and there was a diverse age range, with the mean (SD) age 39.4 (12.4) years. The use of a four-day food diary ensured a good amount of dietary detail was obtained. The use of DXA allowed body fat percentage to be calculated, which gives a more accurate indication of metabolic health than BMI, which does not account for body composition. The study design was comprehensive in that it allowed for several different anthropometrical markers and metabolic biomarkers to be measured, so gave a well-rounded picture of the metabolic health of the participants.

4.4 Limitations

This study had several limitations. Due to the necessity to travel to Massey University, all participants were based in Auckland, so may not be representative of vegans living outside major urban areas. There was also little ethnic diversity among participants, as most (85%) were New Zealand European. The majority (73.1%) of participants were also female, though it is possible this demographic may be reflective of the makeup of the vegan community in New Zealand. This was also a highly educated population, with 68.2% having a university degree. This may indicate higher socioeconomic status and therefore food security, factors that have a positive effect on metabolic health independent of diet. A convenience sampling method was used, which may naturally bias towards participants who are more health conscious. This study was unable to assess dietary quality, which may have provided more information on the metabolic health effects of different vegan dietary patterns. As this study is a cross-sectional study, it only provides data at one point in time. A longitudinal study would provide more information about the metabolic health status and dietary intake of New Zealand vegans over time. It may also be able to provide some insight into whether a low omega-3 status in an otherwise metabolically healthy vegan population carries the same level of cardiovascular risk as that of an omnivorous population with a low omega-3 index.

4.5 Recommendations and Future Directions for Research

- A national representative study of the New Zealand vegan population may give information on differences, if any, between the rural and urban vegan populations
- Longitudinal studies would be useful to determine the impact of a low omega-3 index result in the context of otherwise optimal cardiometabolic biomarkers
- Dietary pattern analysis of the four-day food diaries would give a clearer picture of the effects of differing vegan dietary patterns on metabolic health
- Analysis of the different sources of plant proteins consumed by New Zealand vegans and their association with body composition would enable advice to be given to the vegan community on the benefits and drawbacks of different sources of plant proteins
- Dietary pattern analysis of the participants’ diets in relation to their metabolic biomarkers and anthropometry will give stronger evidence on which to base dietary recommendations for the New Zealand vegan community.

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Appendices

Appendix A: Supplementary Results

Supplementary Table 1

Regression Analysis of Metabolic Biomarkers

Metabolic Biomarker	Predictors	Unstandardised beta (95% CI)	Standardised beta	Sig.	Adj. R^2
HbA1c	Age (years)	0.082 (0.035, 0.129)	0.290	**<0.001**	0.073
	Sex (female)	-0.505 (-1.646, 0.635)	-0.064	0.383	
	Education	0.264 (-0.420, 0.949)	0.056	0.447	
	Physical activity	0.00 (-0.00, 0.00)	0.000	0.996	
	Saturated fat (% total energy)	0.095 (-0.091, 0.28)	0.080	0.315	
	Dietary fibre (grams/kJ energy)	-45.876 (-516.393, 424.641)	-0.016	0.848	
	Body fat % (*z*-score)	0.016 (-0.532, 0.563)	0.004	0.955	
Total cholesterol	Age (years)	0.038 (0.026, 0.049)	0.467	**<0.001**	0.342
	Sex (female)	-0.111 (0.385, 0.164)	-0.049	0.429	
	Education	0.007 (-0.156, 0.170)	0.005	0.935	
	Physical activity	-0.00 (0.00, 0.00)	-0.024	0.701	
	Saturated fat (% total energy)	0.020 (-0.024, 0.065)	0.060	0.371	
	Dietary fibre (grams/kj energy)	56.865 (-57.017, 170.748)	0.071	0.326	
	Body fat % (*z*-score)	0.212 (0.080, 0.345)	0.209	**0.002**	
LDL-C	Age (years)	0.028 (0.018, 0.037)	0.423	**<0.001**	0.340
	Sex (female)	-0.246 (-0.475, -0.017)	-0.132	**0.035**	
	Education	-0.005 (-0.138, 0.129)	-0.004	0.947	
	Physical activity	0.00 (0.00, 0.00)	0.036	0.565	

	Saturated fat (% total energy)	0.003 (-0.034, 0.039)	0.011	0.874	
	Dietary fibre (grams/kj energy)	37.208 (-57.027, 131.443)	0.057	0.437	
	Body fat % (*z*-score)	0.211 (0.101, 0.321)	0.254	**<0.001**	
HDL-C	Age (years)	0.003 (-0.002, 0.008)	0.102	0.193	0.212
	Sex (female)	0.356 (0.237, 0.475)	0.401	**<0.001**	
	Education	0.056 (-0.014, 0.125)	0.106	0.115	
	Physical activity	-0.00 (0.00, 0.00)	-0.041	0.547	
	Saturated fat (% total energy)	0.018 (-0.001, 0.037)	0.138	0.064	
	Dietary fibre (grams/kj energy)	13.155 (-35.734, 62.044)	0.042	0.596	
	Body fat % (*z*-score)	-0.067 (-0.124, -0.010)	0.170	**0.021**	
Triglycerides	Age (years)	0.017 (0.007, 0.026)	0.275	**<0.001**	0.185
	Sex (female)	-0.455 (-0.692, -0.219)	-0.263	**<0.001**	
	Education	-0.100 (-0.239, 0.039)	-0.097	0.158	
	Physical activity	-0.00 (0.00, 0.00)	-0.093	0.186	
	Saturated fat (% total energy)	-0.006 (-0.044, 0.032)	-0.022	0.765	
	Dietary fibre (grams/kj energy)	1.444 (-96.041, 98.928)	0.002	0.977	
	Body fat % (*z*-score)	0.095 (-0.018, 0.209)	0.123	0.100	
Chol/HDL ratio	Age (years)	0.017 (0.009, 0.026)	0.269	**<0.001**	0.399
	Sex (female)	-0.675 (-0.887, -0.463)	-0.373	**<0.001**	
	Education	-0.117 (-0.242, 0.007)	-0.109	0.065	
	Physical activity	-0.00 (0.00, 0.00)	-0.047	0.433	
	Saturated fat (% total energy)	-0.025 (-0.059, 0.009)	-0.093	0.151	

	Dietary fibre (grams/kj energy)	5.166 (-82.193, 92.524)	0.008	0.907
	Body fat % (*z*-score)	0.258 (0.156, 0.360)	0.317	**<0.001**

Supplementary Table 2

Regression Analysis of Omega-3 Index

Predictors	**Unstandardised beta (95% CI)**	**Standardised beta**	**Sig.**
Age (years)	0.005 (-0.004, 0.015)	0.093	0.248
Sex (female)	0.181 (-0.051, 0.412)	0.109	0.125
Education	0.083 (-0.223, 0.057)	-0.086	0.243
Physical activity	0.00007269 (0.000, 0.000)	0.072	0.319
Polyunsaturated fat (% total energy)	0.004 (-0.039, 0.048)	0.015	0.842
Omega-3 supplement use	0.669 (0.414, 0.924)	0.365	**<0.001**
Body fat % (*z*-score)	0.044 (-0.069, 0.157)	0.061	0.446

Note. Adj. R^2 = 0.136

Supplementary Table 3

Regression Analysis of Anthropometrical Markers

Anthropometrical markers	Predictors	Unstandardised beta (95% CI)	Standardised beta	Sig.	Adj. R^2
Waist circumference	Age (years)	0.157 (0.049, 0.264)	0.182	**0.004**	0.463
	Sex (female)	-7.253 (-9.884, -4.621)	-0.300	**<0.001**	
	Education	-0.092 (-1.654, 1.469)	-0.006	0.907	
	Physical activity	-0.001 (-0.002, 0.001)	-0.055	0.324	
	Saturated fat (% total energy)	-0.142 (-0.571, 0.288)	-0.039	0.516	
	Dietary fibre (grams/kj energy)	-460.198 (-1547.917, 627.521)	-0.053	0.405	
	Body fat % (*z*-score)	5.484 (4.228, 6.739)	0.512	**<0.001**	
Systolic blood pressure	Age (years)	0.389 (0.230, 0.548)	0.359	**<0.001**	0.257
	Sex (female)	-8.982 (-12.883, -5.080)	-0.295	**<0.001**	
	Education	-0.603 (-2.918, 1.712)	-0.033	0.608	
	Physical activity	0.000 (-0.003, 0.002)	-0.007	0.910	
	Saturated fat (% total energy)	-0.709 (-1.345, -0.072)	-0.156	**0.029**	
	Dietary fibre (grams/kj energy)	-1281.179 (-2893.800, 331.441)	-0.118	0.119	
	Body fat % (*z*-score)	1.522 (-0.340, 3.383)	0.113	0.108	
Diastolic blood pressure	Age (years)	0.205 (0.087, 0.323)	0.270	**<0.001**	0.162
	Sex (female)	-2.371 (-5.272, 0.530)	-0.111	0.109	
	Education	-0.405 (-2.126, 1.317)	-0.032	0.643	
	Physical activity	0.000 (-0.002, 0.001)	-0.038	0.592	
	Saturated fat (% total energy)	-0.524 (-0.997, -0.051)	-0.164	**0.030**	

	Dietary fibre (grams/kj energy)	-445.858 (-1644.906, 753.189)	-0.059	0.464	
	Body fat % (*z*-score)	2.109 (0.725, 3.493)	0.223	**0.003**	
Body fat percentage	Age (years)	0.201 (0.137, 0.264)	0.339	**<0.001**	0.520
	Sex (female)	11.306 (9.594, 13.017)	0.680	**<0.001**	
	Education	-0.671 (-1.683, 0.342)	-0.068	0.193	
	Physical activity	0.000 (-0.001, 0.001)	-0.041	0.443	
	Saturated fat (% total energy)	-0.194 (-0.474, 0.087)	-0.078	0.175	
	Dietary fibre (grams/kj energy)	-914.480 (-1610.757, -218.203)	-0.154	**0.010**	
	Protein intake (% total energy)	-0.265 (-0.461, -0.069)	-0.139	**0.008**	

Appendix B: Study Questionnaires and Material

Participant Information Sheet

Participant Information Sheet

Health and Vegan Diet

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

A clinical investigation project included in Phase 2 of The Vegan Health Research Programme

Lead Researcher: Professor Pamela von Hurst

Study Site: Human Nutrition Research Unit, Massey University, Albany

Contact phone number: 09 414 0800 ext 43657

Ethics committee ref.: 2022 EXP 12312

You are invited to take part in a study investigating the impact of a vegan diet on your health**.** Whether or not you take part is your choice. If you want to take part now, but change your mind later, you can pull out of the study at any time.

This Participant Information Sheet will help you decide if you'd like to take part. It sets out why we are doing the study, what your participation would involve, what the benefits and risks to you might be, and what would happen after the study ends. We will go through this information with you and answer any questions you may have. You do not have to decide today whether or not you will participate in this study. Before you decide you may want to talk about the study with other people, such as family, whānau, friends, or healthcare providers. Feel free to do this.

This form is 8 pages. Please make sure you have read and understood all the pages.

VOLUNTARY PARTICIPATION AND WITHDRAWAL FROM THIS STUDY

Participation in this study is completely voluntary. You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular questions
- Withdraw from the study at any time
- Ask any questions about the study at any time during participation
- Provide information on the understanding that your name will not be used

- Be given access to a summary of the study findings when it is concluded
  Withdrawing from the study, should you choose to, will not result in any disadvantage to you.

What is the purpose of the study?

Interest in the vegan lifestyle is growing, and NZ ranks the fifth most vegan country in the world. A vegan diet tends to have some health benefits, but at the same time it might be associated with nutrient deficiencies.

These deficiencies could have significant health consequences if they occur during critical period of life (for example, pregnancy or the rapid growth and developmental stages). Therefore, dietary guidelines stress that those who follow strict vegetarian or vegan diets may need extra information and/or support to ensure that they meet their nutrient needs. Our search has not found any studies to date that have investigated nutritional status, nutrient/food intake, motivations and nutritional knowledge and their sources of NZ vegans.

The aims of this study are to investigate nutritional status, nutrient/food intake, reasons for becoming vegan, nutrition knowledge and sources of nutrition information, and gastrointestinal discomfort symptoms among NZ vegans.

How is the study designed?

This study will involve 220 men and women aged 18 years or older, who have been on a vegan diet for at least two years. Participants will take part in online or telephone screening to check eligibility. If eligible they will visit the Human Nutrition Unit at Massey University, once for approximately 90 minutes,

Participants will be required to have bone density, body composition, and blood pressure measurements, complete online questionnaires regarding health, demographics, lifestyle, physical activity, motivations for following a vegan diet, dietary intake, nutrition knowledge, and sources of nutrition knowledge, and complete a 4-day diet record. In addition, participants will be asked to provide a non-fasted blood sample.

Who can take part in the study?

Men and women aged 18 years or older, who have been following a vegan diet for at least two years will be included in this study. Women who are pregnant or have any likelihood of being pregnant will be excluded from this study. Participants will complete a short screening questionnaire to ensure they meet inclusion criteria.

What will my participation in the study involve?

If you decide to take part in this study, after you have read and had time to consider the information in this information sheet, you will be required to complete the screening questionnaire. Screening involves answering a few inclusion criteria questions, this can be done at home either online or on the phone, and takes approximately five minutes. Your answers to this questionnaire will help us to see if you are eligible to take part in this study or not.

If you are eligible to take part in this study, you will be required to visit Human Nutrition Unit at Massey University in Albany on one occasion for data collection. Prior to your visit to Massey University, we will send you a consent form, some questionnaires that need to be completed online, and a diet diary. For the online questionnaires, we will ask you to:

- Complete demographic, health, lifestyle, and physical activity questionnaires.
- Complete a questionnaire to assess motivations for following a vegan diet
- Complete a questionnaire to assess dietary intake
- Complete a questionnaire to assess nutritional information and their sources
- Complete a questionnaire to assess gastrointestinal discomfort symptoms

For the diet diary, we request that for 4 days you record everything you eat and drink. Instructions will be provided in more detail at your visit.

A researcher will make an appointment with you at your convenience You will be required to not have caffeinated drinks and not exercise for 2hrs prior to the visit. This visit will take approximately 90 minutes and you will be reimbursed for your travel.

At this appointment you will first be asked to hand in the signed consent form for participating in the study and you will have the opportunity to ask any questions you may have about the study. During this visit, we will ask you to

- Have weight, height, and waist and hip circumferences measured by a trained researcher.
- Have bone density and body composition measured using dual-energy X-ray absorptiometry (DXA). This machine uses very low dose X-rays to measure the bone density of your hip and spine, and also measures your body composition (fat mass, lean mass, and bone mass of your body).
- Have blood pressure measured using electronic blood pressure monitor by a trained researcher
- Provide a small venous blood sample (about 20ml which is equivalent to 4 teaspoons). This will be taken by a qualified phlebotomist. It will be used to measure levels of various nutrients in your blood, such as iron and vitamin D.

WHAT WILL HAPPEN TO MY BLOOD SAMPLES?

All samples will be labelled with the participant's unique identity code/number and not by the participant's name.

The blood samples will be stored in a minus 80 degree freezer until the study is completed after which time the biochemical analysis will be conducted. While waiting for data and bloods to be collected from all participants and analysed in one batch, samples will be kept in the freezer at the Nutrition laboratory at Massey University, Building 27, Oteha Rohe campus, Albany.

On completion of the study, samples will be sent to the Canterbury Health Labs to assess vitamins D, B_{12}, folate, iron, lipids, calcium and albumin.

One drop of whole blood sample will be analysed on site at Massey University to assess haemoglobin, and another drop will be applied to a special paper to be sent to CSIRO laboratory in Adelaide to assess polyunsaturated fatty acids.

Participants may ask to withdraw their samples at any time during the study up to the time the samples are analysed. The analysis results in the destruction of the sample.

There may be participants who identify as Māori and if specific concerns develop, the support of Dr Bevan Erueti (Taranaki, Te Ati Haunui-ā-Papārangi, Ngāti Tūwharetoa), Associate Dean Māori, will be afforded. Dr Erueti has expressed that he is happy to act in the capacity of advisor and if required will assist and facilitate the projects Māori agenda and ensure that relational aspects of trust and appreciation are upheld with Māori participants. We are also aware that a diversity of beliefs and cultural concerns regarding the removal, storage and transport of tissue samples and these should be discussed with your whānau (family) or take advisement from hapū and iwi leaders. Nonetheless, the right to decline or withdraw from the study can be done at any stage of the project.

What are the possible risks of this study?

The DXA has X-ray beams of different energies and, while no dose of radiation is harmless, this dose is very low and unlikely to cause harm. The total effective dose of radiation to which you will be exposed to is 10.8 microsieverts (μSv), which is much lower than the range normally used in medical diagnostics. To place this in perspective, the amount of radiation an individual would receive from flying in an aircraft to the United Kingdom equates to an effective dose about six times that received from the study. The effective dose received by the participants from the study is also equivalent to about 2 days of background radiation to which all New Zealanders are exposed. This procedure is quick, non-invasive and completely painless. The room is private, and the staff are experienced and certified.

Some people may have a fear of having a blood sample taken or experience discomfort when blood samples are taken. Occasionally a slight bruising will result. The bruising usually disappears within a day or two. Blood samples will be taken by a trained phlebotomist. There may be social or cultural discomfort from having a blood sample, bone density, body composition, and blood pressure measurements taken, however, you will be treated with respect, and privacy will be ensured. We will explain all measurements being taken and ask for your permission prior to undertaking these measurements. You may also be accompanied by a support person if you wish. Every effort will be made to ensure your comfort and respect your participation.

WHAT ARE THE POSSIBLE BENEFITS OF THIS STUDY?

- You will be contributing to a greater understanding of the health implications of a vegan diet.
- You will not be charged for any of the measurements conducted for the study
- You will be provided with your body composition results, blood test results and a nutrient analysis of your diet from your 4-day diet diary.
- You will get a summary of the study results.

Will any costs be reimbursed?

Participants will not incur any costs as part of being involved in the study and will receive reimbursement for travel ($20 in vouchers).

What if something goes wrong?

If you were injured in this study, you would be eligible to apply for compensation from ACC just as you would be if you were injured in an accident at work or at home. This does not mean that your claim will automatically be accepted. You will have to lodge a claim with ACC, which may take some time to assess. If your claim is accepted, you will receive funding to assist in your recovery.

If you have private health or life insurance, you may wish to check with your insurer that taking part in this study won't affect your cover.

What will happen to my information?

During this study the researchers will record information about you and your study participation. This includes the results of any study assessments. You cannot take part in this study if you do not consent to the collection of this information.

Identifiable Information

Identifiable information is any data that could identify you (e.g. your name, date of birth, or address). The following groups may have access to your identifiable information:

- Research staff (to complete study assessments)

- Government agencies, like HDEC, ACC and its representatives, **if** you make a compensation claim for study-related injury. Identifiable information is required in order to assess your claim.

De-identified (Coded) Information

To make sure your personal information is kept confidential, information that identifies you will not be included in any report generated by the researcher. Instead, you will be identified by a code. The researcher will keep a list linking your code with your name, so that you can be identified by your coded data if needed.

The results of the study may be published or presented, but not in a form that would reasonably be expected to identify you.

Anonymised Information

The lead researcher may remove the code from your de-identified information – this is called 'anonymisation'. This makes it very difficult (but not impossible) to identify the information that belongs to you. The researcher may share this anonymised information with other researchers on request for the purpose of accumulating data from individual studies. The anonymous/anonymised data is unable to be accessed, corrected, or withdrawn; and return of individual results will not be possible.

Future Research Using Your Information

If you agree, your fully anonymous/anonymised information may be used for future research related to veganism. This is optional and you could still participate in the present study if you do not agree.

This future research may be conducted overseas. You will not be told when future research is undertaken using your information. Your information may be shared widely with other researchers. Your information may also be added to information from other studies, to form much larger sets of data.

You will not get reports or other information about any future research that is done using your information.

Your information may be used indefinitely for future research unless you withdraw your consent. However, it may be extremely difficult or impossible to access your information, or withdraw consent for its use, once your information has been shared for future research.

Security and Storage of Your Information

Your identifiable information is held at Massey University during the study. After the study it is transferred to a secure archiving site and stored for at least 10 years, then destroyed. Your coded information will be entered into electronic case report forms. Coded study information will be kept in secure, cloud-based storage indefinitely. All storage will comply with local and/or international data security guidelines.

The linked data in this study will be destroyed at the end of the study.

Risks.

Although efforts will be made to protect your privacy, absolute confidentiality of your information cannot be guaranteed. Even with coded and anonymised information, there is no guarantee that you cannot be identified. The risk of people accessing and misusing your information (e.g. making it harder for you to get or keep a job or health insurance) is currently very small but may increase in the future as people find new ways of tracing information.

Rights to Access Your Information

You have the right to request access to your information held by the research team. You also have the right to request that any information you disagree with is corrected.

Please ask if you would like to access the results of your scan (body composition) during the study. You can’t access other study-specific information (e.g. diet analysis and blood test results) during the study, because these data will be analysed when the data from all participants are collected and the study is over.

If you have any questions about the collection and use of information about you, you should ask researcher.

Rights to Withdraw Your Information

You may withdraw your consent for the collection and use of your information at any time, by informing the study researchers.

If you withdraw your consent, your study participation will end, and the study team will stop collecting information from you.

Information collected up until your withdrawal from the study will continue to be used and included in the study. This is to protect the quality of the study.

WHAT HAPPENS AFTER THE STUDY OR IF I CHANGE MY MIND?

If you wish to withdraw from the study, please inform one of the research team. Information and data collected up until your withdrawal from the study will continue to be used and included in the study. This is to protect the quality of the study.

The data will be used for the purposes of this study, and fully anonymised, selected outcomes may be shared with other researchers on request for the purpose of accumulating data from individual studies. Only investigators and administrators of the study will have access to personal information, and this will be kept secure and strictly confidential. Participants will be identified only by a study identification number. Results of this project may be published or presented at conferences or seminars. No individuals will be able to be identified.

At the end of this study the list of participants and their study identification number will be disposed of. Any raw data on which the results of the project depend will be retained in secure storage for 10 years, after which it will be destroyed.

All participants will have access to a summary of the project findings when the study is completed.

CAN I FIND OUT THE RESULTS OF THE STUDY?

All participants will have access to a summary of the project findings when it is completed. However, findings of any future research conducted using fully anonymised data collected in this project will not be made available to participants.

WHO IS FUNDING THE STUDY?

This study is funded by the Lottery Health Project Grant.

Participants will not incur any costs for taking part in the study and will be reimbursed for travel.

WHO HAS APPROVED THE STUDY?

This study has been approved by an independent group of people called a Health and Disability Ethics Committee (HDEC), who check that studies meet established ethical standards. The Central Health and Disability Ethics Committee has approved this study.

Who do I contact for more information or if I have concerns?

If you have any questions, concerns or complaints about the study at any stage, you can contact:

Dr. Hajar Mazahery, study manager

Email: h.mazahery@massey.ac.nz

Rebecca Paul, research assistant

Phone: 022 1294112

Email: veganstudy@massey.ac.nz

The other members of the research team are: Professor Pamela von Hurst, Associate Professor Cathryn Conlon, Associate Professor Kathryn Beck, and Dr. Rachel Batty (College of Health, Massey University).

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone: 0800 555 050
Fax: 0800 2 SUPPORT (0800 2787 7678)
Email: advocacy@advocacy.org.nz
Website: https://www.advocacy.org.nz/

For Maori health support please contact:

Dr Bevan Erueti, Taranaki, Te Ati Haunui-ā-Papārangi, Ngāti Tūwharetoa, Associate Dean Māori

Phone: 06 356 9099 Ext 83087

Email: B.Erueti@massey.ac.nz

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone: 0800 4 ETHIC

Email: hdecs@health.govt.nz

Food Diary Template (sample of instructions and Day 1)

Health and Vegan Diet

4 Day Food Record

Thank you very much for taking part in this study. We are extremely grateful for your time, effort and commitment

If you have any questions, please contact Rebecca Paul on 022 1294112 (Email: veganstudy@massey.ac.nz)

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

Please bring the food diary with you when you come in for assessment at Massey University.

4 day food diary - what to do?

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

- **Please complete the diary on consecutive days for 1 weekend day and 3 week days at your convenience. For example, Sunday, Monday, Tuesday and Wednesday OR Wednesday, Thursday, Friday and Saturday.**

- If possible record food at the time of eating or just after – try to avoid doing it from memory at the end of the day.

- Include all meals, snacks, and drinks, even tap water.

- Include anything you have added to foods such as sauces, gravies, spreads, dressings, etc.

- Write down any information that might indicate size or weight of the food to identify the portion size eaten.

- Use a new line for each food and drink. You can use more than one line for a food or drink. See the examples given.

- Use as many pages of the booklet as you need.

- You can also save any packets such as muesli bar wrappers and bring them in with your food diary

Describing Food and Drink

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

General description	Food record description
Breakfast example – cereal, milk, sugar	2 Weetbix (Sanitarium) 1 cup So Good unsweetened almond milk 1 tsp Chelsea white sugar

Lunch – Meat Free Bacon Style Rashers sandwich and home-made fries	2 slices of wholegrain bread (Vogels) 2 slices Vegie Delights Meat Free Bacon Style Rashers 25g zenzo Dairy Free Vegan Cheddar Cheese Alternative 2 tsp Tablelands Dairy Free Buttery Spread ½ cup fries (home-made, deep fried in Pam's sunflower oil) ½ Tbs vegan aioli (Heinz Mayonnaise Vegan Aioli) Water 1 cup to drink
Dinner – Vegan lentils spaghetti bolognese	½ cup lentil sauce (see attached recipe) 1 cup spaghetti pasta (Homebrand)
Snacks	Tam & Luke Snack Ball Salted Caramel (2 balls, 28g) 1 small banana 2 Salada crackers with 1 tsp peanut butter 20g Doritos Spicy Sweet Chili Flavored Tortilla Chips

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

General description	**Food record description**
Potatoes	2 medium size potatoes cut in slices and fried in 2tbs canola oil 2 large potatoes with skin (boiled)
Black bean and kumara burger	85g black bean and kumara burger (recipe provided) pan-fried in 2tsp olive oil 85g black bean and kumara burger (recipe provided) oven baked

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

General description	Food record description
Rice	1 cup cooked Jasmine rice (cooked on stove top)
Meat alternatives	1 cup of cooked lentil sauce or 5 oven baked chicken style strips (Fry's)
Vegetables	½ cup cooked mixed vegetables (Wattie's peas, corn, carrots)

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

General description	Food record description
Apple	1 x 120g Granny Smith Apple (peeled, core not eaten – core equated to ¼ of the apple)
Fried chicken alternative strips	100g chicken alternative strips (100g includes batter); fried in 3 Tbsp Nuttelex buttery margarine

General description	Food record description
Milo	I x cup Milo made with plant based Milo powder and 150mls So Good unsweetened almond milk, 100 ml hot water. No sugar

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

Recording the amounts of food you eat

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

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

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

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

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

- Using comparisons – e.g. Meat alternative equal to the size of a pack of cards, a scoop of vegan chocolate ice cream equal to the size of a hen's egg.

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

General description	**Food record description**
Cheese alternatives	1 heaped tablespoon of grated dairy free cheddar cheese 1 slice dairy free cheddar cheese (8.5 x 2.5 x 2mm) 1 cube dairy free cheddar cheese, match box size

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

- ***Please try to eat as normally as possible – e.g., Don't adjust what you normally eat just because you are keeping a diet record and be honest! This record will give us important information about your diet, and help us identify any possible deficiencies which we can then help you correct.***

Example day

Time food was eaten	**Complete description of food (food and beverage name, brand, variety, preparation method)**	**Amount consumed (units, measures, weight)**
Example 7:55am	Sanitarium Weetbix	2 weetbix
" "	So good unsweetened almond milk	150ml
" "	Chelsea white sugar	2 heaped teaspoons
" "	Orange juice (Citrus Tree with added calcium – nutrition label attached)	1 glass (275 ml)
10.00am	Raw Apple (gala)	Ate all of apple except the core, whole apple was 125g (core was ¼ of whole apple)
12.00pm	Home-made pizza (recipe attached)	1 slice (similar size to 1 slice of sandwich bread, 2 Tbsp tomato paste, 4 olives, 2 meat free bacon style rashers (zenzo), 1 Tbsp chopped spring onion, 3 Tbsp vegan mozzarella cheese)
1.00pm	Water	500ml plain tap water
3.00pm	Biscuits	2 x Lotus Biscoff biscuits
6.00pm	Lasagne	½ cup cooked Sunfed Bull free beef meat alternative mince, 1 cup cooked Budget lasagne shaped pasta, ½ cup homemade (recipe attached) vegan bechamel sauce made with soy milk (So Good, regular), ½ cup mixed vegetables (Pam's carrots, peas and corn), 4 Tbsp Veesey grated pizza blend cheese
6.30pm	Vegan banana cake with chocolate icing (homemade, recipe attached)	1/8 of a cake (22cm diameter, 8 cm high), 2 Tbsp chocolate icing
" "	Tip Top Crave dairy free salted caramel fudge frozen dessert	1/2cup (g) (125g)

Date________________________________ **DAY 1**

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

Date________________________________ DAY 1 continued

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

Recipes (Day 1)

Health and Vegan Diet Demographic Questionnaire

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

Health and Vegan Diet

Health and Demographic Information

Please answer all questions. All the information you give us is in confidence and will only be used of the purposes of this study. If you need any help to complete questions, please ask one of the research team.

1. Do you have or have you ever had any acute illness?

   [ ] Yes
   [ ] No

2. If yes, please provide more details (including the diagnosis, date of diagnosis, by whom you were diagnosed, and any details you may think is relevant) below:

   ____
   ____
   ____

3. Do you have or have you ever had any chronic illness?

   [ ] Yes
   [ ] No

4. If yes, please provide more details (including the diagnosis, date of diagnosis, by whom you were diagnosed, and any details you may think is relevant) below:

   ____
   ____
   ____

5. Have you ever been diagnosed with any bone fracture (broken bone)?

   [ ] Yes
   [ ] No

6. If yes, please provide more details (which bone, age when it happened, how did it happen)

   ____
   ____
   ____

7. Do you usually have elevated blood pressure (systolic blood pressure ≥120 mmHg and/or diastolic blood pressure ≥75 mmHg)?

[ ] Yes
[ ] No
[ ] Unsure

8. If yes, please provide more details (elevated systolic blood pressure, elevated diastolic blood pressure or both?)

____
____
____

9. Have you ever been diagnosed with iron deficiency?

[ ] Yes
[ ] No
[ ] Unsure

10. If yes, please provide more details about your iron deficiency (self-diagnosed or diagnosed by a health care provider, date and treatment)

____
____
____

11. Do you get nose bleeds?

[ ] Yes
[ ] No

12. If yes, how often do you get a nose bleed?
_______________ Times a month or _______________ Times a year

13. If yes, how heavy are your nose bleeds?

[ ] Light
[ ] Medium
[ ] Heavy

14. Have you had any blood loss (other than periods or nose bleeds) such as wounds, regular scratches from contact sports, blood in stools, or urine in the past year?

[ ] Yes
[ ] No

15. If yes, please describe below.

____
____
____

16. Have you had any medical condition which has resulted in blood loss?

[ ] Yes
[ ] No

17. If yes, please describe and give approximate date below.

____
____
____

18. Do you donate whole blood (i.e. not plasma)?

[ ] Yes
[ ] No

19. If yes, when did you last donate blood?

Date _________ / ________ /________
Day Month Year

20. If yes, how many times have you donated whole blood in the past year?

________________________ (times in the past year)

21. Have you ever had iron infusion?

[ ] Yes
[ ] No

22. If yes, please provide details (reasons and date of infusion)

____
____
____

23. Have you had a blood transfusion in the last year?

[ ] Yes
[ ] No

24. If yes, please provide details (reason and date of transfusion)

____
____
____

25. Do you currently smoke?

[ ] Yes
[ ] No

26. If yes, how often do you smoke

[ ] Occasionally
[ ] A few times per week
[ ] Daily

27. If no, have you ever smoked?

[ ] Yes
[ ] No

28. If yes, how often did you use to smoke?

[ ] Occasionally
[ ] A few times per week
[ ] Daily

29. Are you currently taking any medication (excluding nutritional supplements)?

[ ] Yes
[ ] No

30. If yes, please state what medication you are taking and why?

____
____
____

31. Has any of your first-degree family members (parents and grandparents) had osteoporosis?

[ ] Yes
[ ] No
[ ] Unsure

32. Has any of your first-degree family members (parents and grandparents) had the following illnesses when they were younger than 50 years old?

	Yes	No	Unsure
Cardiovascular diseases (i.e. angina, heart attack, transient ischaemic attack, stroke)	[ ]	[ ]	[ ]
Hypertension	[ ]	[ ]	[ ]
Diabetes	[ ]	[ ]	[ ]
Hypercholesterolemia	[ ]	[ ]	[ ]

33. In general, would you say your health is..
[ ] Excellent
[ ] Very good
[ ] Good
[ ] Fair
[ ] Poor

Questions specific to women

34. Which of the following BEST describes your current Menstrual/Menopausal status?

[ ] Never menstruated
[ ] Still menstruating
[ ] Going through menopause
[ ] Postmenopausal
[ ] Other (Please explain)

35. Have you had a period in the last 3 months? (not including postmenopausal women)

[ ] Yes
[ ] No

36. How regular are your periods (21-34 days)?

[ ] Regular
[ ] Irregular

37. How many days do you usually have between periods? (for instance, counting from the first day of your last period to the day you expect your next period to start)

_______________ days

38. Do you know when your last period started?
39.

[ ] Yes
[ ] No

40. When did your last period start?

_________ / ________ /________
Day Month Year

41. How many days does your period usually last?

_______________ days

42. Have you been pregnant within the last year?

[ ] Yes
[ ] No

43. If yes, did the pregnancy result in any significant blood loss that you are aware of? (Please comment below)

44. Are you on hormonal contraceptives?

[ ] Yes
[ ] No

45. If yes, please describe details (i.e. injection, IUD, implant, oral)

46. Do you currently take Hormone Replacement Therapy?

[ ] Yes
[ ] No

47. If yes, please provide more details (type of Hormone Replacement Therapy and for how long)

Demographics (7 questions)

48. When were you born?

___________ Day (DD) ________ Month (MM) _______ Year (YYYY)

49. What is your gender?

[ ] Female
[ ] Male
[ ] Gender diverse
[ ] Other (Please state)

50. Which ethnic group do you belong to? Tick whichever applies to you (you may check [x] more than one box)

[ ] New Zealand European
[ ] Māori
[ ] Samoan
[ ] Cook Islands Māori
[ ] Tongan
[ ] Niuean
[ ] Chinese
[ ] Indian
[ ] Others, eg DUTCH, JAPANESE, TOKELAUAN.
Please state below.
a) ______________________________
b) ______________________________

51. What is your HIGHEST level of EDUCATION?

[ ] Lower than high school
[ ] High school
[ ] Diploma/certificate
[ ] Bachelor's degree
[ ] Master's degree
[ ] Doctorate or PhD

52. Do you have tertiary education in the following fields? (you can choose more than one answer)

[ ] Medicine
[ ] Nutrition/Dietetics
[ ] Nursing
[ ] Midwifery
[ ] Other health related fields (Please specify)
[ ] Others (Please specify)
[ ] Not applicable

53. What is your current employment status?

[ ] Full time
[ ] Part time
[ ] Volunteer
[ ] Seeking opportunities currently
[ ] Retired
[ ] Other (e.g., caregiver, studying, homemaker). Please describe.

54. What is your marital status?

[ ] Married / cohabiting / civil union / de facto
[ ] Divorced / Separated
[ ] Widowed
[ ] Single
[ ] Other (please describe)

55. How many children have you given birth to? (If female)

[ ] No children
[ ] 1 child
[ ] 2 children
[ ] 3 children
[ ] 4 children
[ ] 5 or more children

Dietary Practices and Supplement Use Questionnaire

Health and Vegan Diet

Dietary Practices and Supplement Use

Please answer all questions. All the information you give us is in confidence and will only be used of the purposes of this study. I you need any help to complete questions, please ask one of the research team.

VEGANISM MOTIVATION

1. How long have you been following a vegan lifestyle?

	2 to 4 years	**5 to 10 years**	**>10 years**
I have been a vegan	[ ]	[ ]	[ ]

2. On a scale of 1 (not important) to 7 (very important) rate the importance of each of the following reasons for you to EXCLUDE MEAT OR ANIMAL PRODUCTS from your diet.

		Not important		**Moderately important**			**Very important**	
		1	**2**	**3**	**4**	**5**	**6**	**7**
1	I want to be healthy							
2	Plant-based diets are better for the environment							
3	Animals do not have to suffer							
4	Animals' rights are respected							
5	I want to live a long time							
6	Plant-based diets are more sustainable							
7	I care about my body							
8	Eating meat is bad for the planet							
9	Animal rights are important to me							
10	Plant-based diets are environmentally-friendly							
11	It does not seem right to exploit animals							
12	Plant products have less of an impact on the environment than animal products							
13	I am concerned about animal rights							
14	My health is important to me							
15	I don't want animals to suffer							

3. There might be other reasons for following a vegan diet. On a scale of 1 (NOT IMPORTANT) to 7 (VERY IMPORTANT), rate the importance of each of the following reasons for you to EXCLUDE MEAT OR ANIMAL PRODUCTS from your diet.

		Not important		**Moderately important**			**Very important**	
		1	**2**	**3**	**4**	**5**	**6**	**7**
1	Cultural/religious beliefs							
2	Allergy/intolerance to animal-based foods							
3	Having a vegan partner or family member							
4	Having a vegan friend							
5	Having a vegan classmate							
6	Having a vegan co-worker/colleague							

DIETARY HABITS

4. On a scale of 1 (NOT AT ALL IMPORTANT) to 5 (EXTEREMELY IMPORTANT), rate the importance of other people's support in helping you following a vegan diet.

[ ] 1 (not important)
[ ] 2 (slightly important)
[ ] 3 (moderately important)
[ ] 4 (very important)
[ ] 5 (extremely important0

5. In a typical week, how often do you eat the following MEALS during the week?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always
Breakfast	[ ]	[ ]	[ ]	[ ]	[ ]
Lunch	[ ]	[ ]	[ ]	[ ]	[ ]
Dinner	[ ]	[ ]	[ ]	[ ]	[ ]

6. In a typical week, how often you eat the following MEALS at the weekend?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always
Breakfast	[ ]	[ ]	[ ]	[ ]	[ ]
Lunch	[ ]	[ ]	[ ]	[ ]	[ ]
Dinner	[ ]	[ ]	[ ]	[ ]	[ ]

7. In a typical week, where are most of your..?

	At home	Out	Don't eat meal
Breakfast	[ ]	[ ]	[ ]
Lunch	[ ]	[ ]	[ ]
Dinner	[ ]	[ ]	[ ]

8. How much responsibility do you have for:

	Little or none	About half	Most or all
Food shopping?	[ ]	[ ]	[ ]
Planning meals?	[ ]	[ ]	[ ]
Preparing meals?	[ ]	[ ]	[ ]

9. What type of food do you preferentially buy? (you can choose more than one answer)

[ ] Pre-cooked meals
[ ] Fresh foods
[ ] Frozen foods
[ ] Canned foods
[ ] Other (please state)
[ ] I don't do food shopping

10. How often do you eat convenient/frozen meals?
[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

11. Concerning fat content in food products, how often you have the followings?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always	Don't know
Non-fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Low fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Reduced fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
High fat products	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

12. How often do you use following cooking methods to cook the foods you eat?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always	Don't know
Boiling/Steaming	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Stir-frying	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Deep-fat frying	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Baking/Microwave/Grill	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

13. What type of oil do you usually use in cooking (e.g., for frying, roasting, etc.)? (You can choose more than one answer).

[ ] Coconut oil
[ ] Olive oil, canola oil, avocado oil, soybean oil, peanut oil, rice bran oil
[ ] Sunflower oil, corn oil, safflower oil, cottonseed oil, sesame seed oil, grapeseed oil

[ ] Other oil (please state)
[ ] I don't use oil in cooking
[ ] Don't know

14. How often do you add salt to your foods/meals?

	Never	Rarely (1/4 of the time)	Sometimes (1/2 of the time)	Usually (3/4 of the time)	Always	Don't know
Whilst cooking	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
At the table to meals/snacks	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

15. Are you on a doctor-prescribed low sodium diet?

[ ] Yes
[ ] No

16. What type of milk do you usually have?

[ ] Soy milk (regular)
[ ] Soy milk (light)
[ ] Soy milk (unsweetened)
[ ] Soy milk (protein plus)
[ ] Coconut milk (regular)
[ ] Coconut milk (light)
[ ] Coconut milk (unsweetened)
[ ] Oat milk
[ ] Rice milk
[ ] Almond milk (regular)
[ ] Almond milk (high protein)
[ ] Almond milk (unsweetened)
[ ] Cashew milk
[ ] Peanut milk
[ ] Seeds milk
[ ] Other milk (please state)
[ ] I don't use/drink milk
[ ] Don't know

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

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

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

[ ] Monounsaturated fat margarine (e.g. spreads based on olive oil, rice bran oil , canola oil)
[ ] Polyunsaturated fat margarine (e.g. spreads based on sunflower oil)
[ ] Light monounsaturated fat margarine (e.g. Olivio spread light)
[ ] Light polyunsaturated fat margarine (e.g. Flora spread light)
[ ] Plant sterol enriched margarine - both full and low fat varieties (e.g. ProActive, Logical)
[ ] Other (please state)
[ ] I don't use spreads on bread
[ ] Don't know

19. How often do you eat savory snacks such as potato chips?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

20. How often do you eat sweet snacks such as biscuits, cakes, sweets, lollies, chocolate or ice blocks or puddings (e.g., fruit pies, crumbles, sponge puddings, steamed puddings)?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

21. How often do you have the following drinks? cordials or fizzy drinks (do not include diet or low-calorie varieties)?

	Less than once a week	Once per week	2 or more times per week	Don't know
Cordials (do not include diet or low calorie variety	[ ]	[ ]	[ ]	[ ]
Diet or low calorie cordials	[ ]	[ ]	[ ]	[ ]
Fizzy drinks (do not include diet or low calorie variety)	[ ]	[ ]	[ ]	[ ]
Diet or low calorie fizzy drinks	[ ]	[ ]	[ ]	[ ]

22. How often do you eat processed/ultra-processed foods?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 times per week
[ ] 3 times per week
[ ] 4 times per week

[ ] 5 times per week
[ ] 6 times per week
[ ] 7 or more times per week
[ ] Don't know

23. How often do you eat at a restaurant/café?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

24. How often do you eat at a fast food outlet?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

25. How often do you eat meal with friends?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

26. How often do you eat at establishments such as work/education canteen?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

27. How often do you eat convenient/frozen meals?

[ ] Never
[ ] Less than once a week
[ ] Once per week
[ ] 2 or more times per week
[ ] Don't know

SUPPLEMENT USE

28. For the following NUTRIENT supplements, please check [x] the *YES* column and fill in the dose and brand name for those you USUALLY use; then state how often you use the supplement. For those you do not use, check [x] the ***NO column***.

Nutrient supplement	Yes	No	Dose	Brand name	How often you use the supplement (please provide more details)
Calcium					
Vitamin D					
Vitamin B12					
B vitamins					
Zinc					
Iron					
Folate					
Iodine					
Selenium					
Multivitamin/ supplement					
Mineral supplement					
Omega-3 fatty acids					
Amino acids (please specify)					
a)					
b)					
c)					
Others (specify below)					
a)					
b)					
c)					
"I do NOT use any nutrient supplements"					[ ] ***True*** [ ] ***False***

29. For the following FOOD/HERBAL/DIETARY supplements, check [x] the *YES* column and fill in the dose and brand name for those you USUALLY use; then state how often you use the supplement. For those you do not use, check [x] the ***NO column***.

Food/herbal/dietary supplement	Yes	No	Dose	Brand name	How often you use the supplement (please provide more details)
Nutritional yeast					
Wheat germ					
Soy/vegetable protein powder					
Spirulina					
Chlorella					
Others (specify below)					
a)					
b)					
c)					
"I do NOT use any food/herbal/dietary supplements"					[ ] ***True*** [ ] ***False***