The relationship between the motivation of health for being vegan and the intake of key nutrients and nutritional status in individuals following a vegan diet.

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

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2024

Abstract

Background: The fundamental principle of veganism is to avoid all possible animal exploitation and therefore, animal ethics has always been a primary motivator. Nowadays, the environment and health are becoming increasingly common motivators for veganism. Omission of all animal products leads to dietary exclusion of vitamin B12, limited intake of omega-3 fatty acids, specifically EPA and DHA, and intake of low bioavailable iron sources. It is unknown whether greater health motivation leads to enhanced intake and status of nutrients.

Objectives: To describe the importance placed on three motivations for following a vegan diet, to investigate the role of health motivation on dietary intake of vitamin B12, iron and the nutritional status of omega-3 fatty acids, vitamin B12, and iron, as well as investigate the role of health motivation on use of vitamin B12, iron and omega-3 supplementation.

Methods: This cross-sectional, observational study recruited participants, who had followed a vegan diet for minimum 2 years. Demographics were obtained from questionnaires. Motivation type was determined using the validated vegetarian eating motives inventory (VEMI) – participants scored the importance of animal ethic, environment and health. Dietary intakes of vitamin B12 and iron, were calculated from a 4-day food diary and assessed against Estimated Average Requirement (EAR). Blood samples were taken to determine status of vitamin B12, haemoglobin, serum ferritin, and omega-3 index.

Results: The study was completed by 212 participants, of whom 73% were female, and the mean (SD) age was 39.43 years (12.41). Animal ethics was a very important motivator for 83.5% of participants, compared to the environment (71.7%), and health (53.3%). Participants motivated the greatest by health had significantly higher intake of iron (p = 0.032) and lower intake of vitamin B12 (p = 0.006) after adjusting for energy intake. No relationship was found between health motivation and omega-3 index. Participants used omega-3 fatty acid, iron and B12 supplementation regardless of level of health motivation. Mean haemoglobin serum concentration was adequate (154.31g.L), as was mean serum ferritin (41.62µg.L), and mean serum vitamin B12 (316.54pmol.L). The mean omega-3 index was 3.15%, with no participants having a cardioprotective score of >8%.

Conclusion: The motivation of health appears to influence intake of iron and vitamin B12. Vitamin B12 status within normal range despite not meeting the EAR and limited vegan sources, indicates the use and importance of supplementation. Iron status shows large consumption of iron rich foods to overcome bioavailability issues. The omega-3 index reveals low cardioprotective omega-3 fatty acid intake.

Acknowledgements

I would like to acknowledge several people for their involvement in this study. Firstly, I would like to thank Professor Pam von Hurst and Professor Cath Conlon for being supportive and encouraging supervisors. I am extremely grateful your feedback and guidance. I would also like to thank Karen Mumme, for your assistance with statistical analysis. Thank you for your time, patience and guidance. I would also like to acknowledge the vital contribution made by Rebecca Paul in recruitment, data collection and food diary organisation and input.

Finally, I would like to thank my partner, for financially and emotionally supporting me through this journey. Thank you for encouraging me every step of the way, this would not have been possible without you.

Table of Contents

List of Tables

List of Figures

List of abbreviations

Abbreviation or symbol	Definition
AD	Alzheimer's disease
AdoCbl	5'-deoxyadenosylcobalamin
ALA	Alpha-linolenic acid
ATP	Adenosine triphosphate
BMI	Body mass index
CNCbl	Cyanocobalamin
CVD	Cardio vascular disease
DHA	Docosahexaenoic acid
DNA	Deoxyribonucleic acid
EAR	Estimated Average Requirement
EPA	Eicosapentaenoic acid
g	Grams
g.day	Grams per day
g.L	Grams per litre
g.L.day	Grams per litre per day
GHG	Greenhouse gas
Hb	Haemoglobin
HDEC	Health and Disability Ethics Committee
IDA	Iron deficiency anaemia
kgCO2e	Kilograms per carbon dioxide equivalents
$kg.m^2$	Kilograms per metres squared
kJ	Kilojoules
LDL	Low density lipoprotein
MeCbl	Methylcobalamin
MFP	Meat, fish, and poultry
mg	Milligrams
mg.day	Milligrams per day
ng	Nanogram
ng.kJ.day	Nanogram per kilojoule per day
ng.L	Nanogram per litre
NRV's	Nutrient Reference Values
NZ	New Zealand
NZD	New Zealand dollars
NZDG's	New Zealand dietary guidelines
OHCbl	Hydroxocobalamin
PBMDA	Plant based meat and dairy analogues
pmol.L	Picomoles per litre
%	Percentage
QALY	Quality adjusted life years
RDI	Recommended dietary intake
SD	Standard deviation
µg	Micrograms

µg.day	Micrograms per day
µg.kJ.day	Micrograms per kilojoule per day
µg.L	Micrograms per litre
UPF	Ultra processed foods
VEMI	Vegetarian eating motives inventory
WHO	World Health Organization
4DFD	4-day Food Diary

Chapter 1: Introduction

1.1 Background

To be vegan means to remove all animal products and by-products from your diet. The term was first coined in 1944, however it was not until the last decade that its popularity extended into mainstream society. According to Google trends NZ has climbed to 4th in the world for veganism popularity, with the most recent study concluding that 1.1% of the NZ population follow a vegan diet (Milfont et al., 2021).

The main motivations reported for becoming and remaining vegan are ethics, environmental, and health (Ghaffari et al., 2022; Janssen et al., 2016). However, other motivations exist such as religious, political, cultural and social beliefs, as well as taste and enjoyment (North et al., 2021). It is rare that these motivations are ever mutually exclusive, with individuals often quoting multiple reasons why they have decided to become vegan (Janssen et al., 2016; North et al., 2021).

Ethical motivations for adopting a vegan diet include reducing the exploitation, physical harm, and death experienced by animals, thereby improving animal welfare. Ethics is often seen as the most obvious motivator due to its fundamental principle of avoiding all possible animal exploitation (The Vegan Society, 2023). Its significance in motivating individuals to begin following a vegan diet is reflected in multiple studies (Janssen et al., 2016; North et al., 2021; Radnitz et al., 2020).

All dietary patterns have varying degrees of impact on the environment. Diets high in meat consumption and animal products are one of the many contributors to globally increasing greenhouse gas (GHG) emissions, temperatures, and climate change, with 18% of global GHG emissions attributed to livestock production (Poore & Nemecek, 2018; Stehfest et al., 2009). On the other hand, a vegan diet has been shown to produce 2.5 times less GHG emissions than a diet that includes meat (>100g.day) (Scarborough et al., 2014). Understanding the impact of dietary choices on the environment may lead individuals to consider the consequences and sustainability of their dietary habits for future generations. This realisation may therefore become a motivation for adopting a vegan diet.

Health has been shown to be a motivator for all dietary patterns, indicating that what individuals believe to be a healthy dietary pattern is subjective. The vegan diet, which can be high in fruit, vegetables, grains and cereals, legumes, and nuts, as well as low in saturated fat has been shown to be protective against developing cardiovascular diseases, type 2 diabetes mellitus, and some cancers (Davey et al., 2003; Dinu et al., 2017; Radnitz et al., 2020; Wegmüller et al., 2017). However, it has also been shown to increase the risk of osteoporosis (Smith, 2006), and development of nutrient deficiencies (Key et al., 2006). As the popularity of the vegan diet has grown, production of vegan ultra processed foods (UPF) has also increased (Gehring et al., 2021). As with all dietary patterns, the diet is only as beneficial as the foods consumed such that consumption of vegan UPF is unlikely to lead to the same beneficial outcomes as following a wholefood vegan diet. Although health is a motivation for becoming vegan, having the knowledge of what a healthy vegan diet is requires considerable nutritional knowledge. As a result, individuals may unknowingly lower their intake of important nutrients.

The vegan diet can be abundant in certain nutrients such as vitamin C, poly-unsaturated fatty acids, fibre, vitamin E, and vitamins B1 and B6 (Bakaloudi et al., 2021). However, due to decreased diet variability and exclusion of animal products it can also be low in nutrients such as vitamin B12, iron, omega-3 fatty acids, vitamin D, vitamin A, calcium, zinc, and iodine (Davey et al., 2003; Key et al., 2006; Raymond, 2020). As plant foods have lower concentrations, bioavailability and even absence of these nutrients it may be difficult or impossible to obtain enough of these through diet alone. Even with the availability and use of plant-based meat analogues, these do not replicate the same nutrient intake as following an omnivore diet. Factors such as an individual's motivation, their nutritional knowledge, and where they obtain nutrition information from, will influence one's ability to plan their diet to achieve adequate intake and prevent the development of nutrient deficiencies (Asp, 1999; Ghaffari et al., 2022; Wardle et al., 2000). Three nutrients that are commonly inadequate in a vegan diet are vitamin B12, omega-3 fatty acids, and iron (Bakaloudi et al., 2021; Davey et al., 2003; Key et al., 2006).

Vitamin B12 is involved in the production of Deoxyribonucleic acid (DNA), red blood cells, and neurotransmitters. Chronic inadequate intake and deficiency can therefore lead to neurological and haematological consequences (Avinash et al., 2017; Pawlak, 2015). Very few plant sources contain vitamin B12 naturally, and those that do contain very small concentrations (Fumio et al., 2014). However, due to an increased trend of consuming less meat, there has been an increase in the development of plant-based meat and dairy analogues (PBMDA), providing a greater number of food options for vegans. These PBMDA are often but not always fortified with vitamin B12. However, even with fortification, obtaining adequate intake is difficult and as such vegans often turn to vitamin B12 supplements to obtain their recommended daily intake (Fuschlberger & Putz, 2023). It is therefore only through careful dietary planning for consumption of vitamin B12, fortified PBMDA and supplementation that vegans can consume enough to maintain body stores.

There are three omega-3 fatty acids our bodies require for optimal health. These are alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). ALA is unable to be synthesised by our bodies so is considered essential to obtain from our diet (Raymond, 2020). Long chain omega-3 fatty acids are involved in many functions in the body such as the formation of cell membranes, signalling molecules, and reducing atherogenic lipids (Sala-Vila et al., 2022). DHA is also specifically involved in developing the brain, retina, and central nervous system (Carlson et al., 2013). Low intake has been linked to poor cardiovascular health, and increased risk of developing Alzheimer's disease (AD) (Cederholm et al., 2013; Heude et al., 2003; Tortosa-Caparrós et al., 2017). ALA is mainly found in plant foods such as walnuts, chia, hemp and flaxseeds, avocado, canola and soybean oils. EPA and DHA however, are primarily found in animal products, with only one plant source available being found in certain species of algae and seaweed (Lane et al., 2022; Meyer et al., 2003). ALA is able to be converted to EPA and DHA however, conversion has shown to be limited at only 0.01 – 10% resulting in inadequate EPA and DHA to meet requirements (Goyens et al., 2005; Swanson et al., 2012).

Iron is a component of haemoglobin, a protein that transfers oxygen in the blood around your body (Raymond, 2020). Inadequate iron intake can result in the development of iron deficiency anaemia (IDA), which has consequences of fatigue, impaired physical activity and poor cognitive function (Clark, 2008). The bioavailability and absorption of iron is influenced by body stores, iron compound consumed (haem vs. non-haem), dosage, as well as intake of both iron enhancers and inhibitors. Whilst haem iron is the main source of iron in animals, non-haem iron is the only type of iron found in plant foods (Raymond, 2020). Non-haem iron has a much lower bioavailability ranging from 1 – 15% compared to a bioavailability of 15 – 40% in haem iron (Hunt, 2003). Plant foods also have lower concentrations of iron, suggesting that adequate iron intake from plant sources alone requires an 80% greater intake than from an omnivorous diet (Hunt, 2003). There are many plant sources of iron including legumes such as kidney beans, chickpeas, and lentils, pumpkin seeds, hemp seeds, spinach, dried apricots, tofu, tempeh, and oats. Meaning that with considerable effort it is possible to consume adequate iron (New Zealand Food Composition Database, 2022). However, a combination of both natural plant sources, fortified PBMDA, and supplements may be necessary to ensure intake is met daily.

The health of vegans in NZ is an under researched topic. Even less is known about the relationship between the level of health motivation one has for becoming vegan and the nutritional intake and status of key nutrients.

1.2 Purpose of the study

The purpose of this study is to determine whether there is an association between the importance of health as a motivator for becoming vegan and the intake and nutrient status of key nutrients of concern in a vegan's diet, specifically vitamin B12, omega-3 fatty acids, and iron.

Although the types of motivation for becoming vegan have been extensively researched, globally very few studies have evaluated whether the motivator of health may impact intake of key nutrients, and nutritional status. There are no studies in New Zealand that have researched the different motivations of vegans let alone possible relationships or impact this may have on intake or nutritional status. Hence, NZ is missing out on valuable insight into the health of our vegan population as well as information that may help shape vegan dietary guidelines.

Therefore, this thesis will contribute to building a clear picture surrounding the health and nutrition of NZ vegans, specifically in relationship to the importance of health motivation and intake and status of key nutrients.

1.3 Aim

To determine the relationship between the motivation of health for being vegan and the intake of key nutrients and nutritional status in individuals following a vegan diet.

1.3.1 Objectives

1. Describe the importance placed on animal ethics, the environment, and health for following the vegan diet.
2. Investigate the role of health motivation on dietary intake of vitamin B12, iron and the nutritional status of omega-3 fatty acids, vitamin B12, and iron.
3. Investigate the role of health motivation on use of vitamin B12, iron and omega-3 supplementation.

1.3.1 Hypotheses

1. That animal ethics will be the largest motivation for following a vegan diet, followed by the environment, then health.
2. Individuals with higher health motivation will have higher intake of iron and vitamin B12 and better nutrient status of iron, vitamin B12 and omega-3 index.
3. Individuals with higher health motivation will use supplementation more as a means of ensuring adequate intake.

1.4 Thesis structure

This thesis is divided into four chapters. **Chapter One** is an introduction to the background and purpose of the study. It includes the aim, objectives, hypotheses and researcher's contributions. **Chapter Two** is a literature review of the most up to date and relevant research in the field of vegan motivations, and nutrients of concern in a vegan diet. **Chapter Three** is the research manuscript which includes the abstract, introduction, methods, results and discussion of findings. The final chapter, **Chapter Four** is the concluding chapter that states how the aim and objectives have been met and acknowledges the impact this research may have on understanding how health motivation can impact vegan nutrition as well as future research recommendations.

The appendices include the recruitment poster, participant information sheet, and questionnaires.

1.5 Researcher contributions

Table 1.1: Summary of researcher's contribution to study

Researcher	**Contribution to Thesis**
Rebecca Pearce MSc Nutrition and Dietetic candidate	Main researcher and author. Data entry of four-day food diaries. Data collection. Contributor to creation of FoodWorks database. Researching, writing, editing, statistical analysis, and interpretation of results.
Professor Pamela von Hurst Primary Academic Supervisor	Principal investigator of the Vegan Health Study. Research proposal and application for research ethics. Assistance with participant recruitment, data collection and management. Assistance with guiding and editing thesis completion.
Professor Cath Conlon Co-Supervisor	Co-investigator in the Vegan Health study. Assistance with guiding and editing thesis completion.

Dr Hajar Mazahery Co-supervisor	Assistance with four-day food diary entry and development of FoodWorks database. Participant recruitment and data collection.
Dr Karen Mumme	Assistance with four-day food diary entry and editing. Assistance with statistical analysis.
Owen Mugridge Project coordinator of the Vegan study	Participant recruitment and data collection.
Rebecca Paul	Assistance with four-day food diary entry and development of FoodWorks database. Participant recruitment and data collection.
Fellow MSc students Abril Clark, Amelia Dunnett, Chelsea Corkindale, Catherine Hassall, Fiona Lee, Lucie Hill	Assistance with four-day food diary entry and development of FoodWorks database.

Chapter 2: Literature review

2.0 Introduction

This chapter reviews the current literature on the topic of motivation for following a vegan diet as well as the nutrients of concern in a vegan diet. Pubmed, Google Scholar, Scopus and Massey Discovery were searched using different combinations of the search terms below (Figure 2.1) derived from the study objectives. Reference lists from relevant articles were also searched.

Date searched: February 2023 – December 2023
Search criteria:
Vegan* OR "vegan diet"
Motivation OR motives OR reason Or incentive
"Animal ethics" OR ethics OR "animal rights" OR "animal welfare" OR morals OR principles
"The environment" OR ecosystem OR "climate change"
Health OR wellbeing OR "physical health"
Iron OR ferritin OR haemoglobin
"Vitamin B12" OR cobalamin
"Omega-3 fatty acids" OR "alpha-linolenic acid", OR "eicosapentaenoic acid", OR "docosahexaenoic acid"
Status OR intake OR consumption
"Supplement use" OR Supplementation
"New Zealand" OR Aotearoa OR Global
Electronic databases: Massey Discovery, Pubmed, Google Scholar, Scopus

Figure 2.1 Search strategy

2.1 Background

The definition of a vegan diet is the omission of all animal products or by-products from an individual's diet. Whether the animal has to be slaughtered for its meat e.g., beef, pork, chicken, fish etc. or is farmed for its by-products e.g., milk, eggs, or honey, a vegan will choose not to consume it. Veganism can extend to lifestyle measures as well such as refusing to purchase leather goods or skincare products that have been tested on animals or contain animal products. The term was first coined in 1944, however it is not until the last decade where its popularity has extended into mainstream society (The Vegan Society, 2023). According to Google trends New Zealand has climbed to 4th in the world for veganism popularity, with the most recent study concluding that 1.1% of the NZ population follow a vegan diet (Milfont et al., 2021). On an individual level, these shifts towards complete animal product omission can arise for many reasons. As defined by the Vegan Society the purpose of becoming vegan is to "promote the development and use of animal-free alternatives for the benefit of animals, humans and the environment" (The Vegan Society, 2023). However, the complex nature of humans means the motivations for becoming and staying vegan can be more nuanced.

Every individual must meet their nutritional requirements of vitamins and minerals through food alone or with the help of supplements. Plant foods are known to be low in vitamin B12, iron, long chain omega-3 fatty acids, vitamin D, vitamin A, calcium, zinc, iodine, and protein (Craig, 2009; Key et al., 2006; Raymond, 2020). They are also incomplete protein sources. Deficiencies in these micronutrients can have long term adverse effects on bone health, immune function, energy levels, muscle growth and repair, and cognitive development (Key et al., 2006; Smith, 2006). Careful consideration of a vegan's diet is necessary to meet recommended nutrient intakes and reduce the risk of developing nutritional deficiencies and negative health outcomes.

Conversely, vegan diets have been found to have beneficial health outcomes from greater daily consumption of fresh fruits, vegetables, nuts and seeds, legumes, and cereals which are rich in anti-oxidants, fibre, and low in saturated fats (Davey et al., 2003; Wegmüller et al., 2017). Health benefits have been found to include reduced risk of developing type 2 diabetes mellitus, reduced total cancer incidence, reduced mortality risk from cardiovascular disease (CVD), lower LDL cholesterol and total cholesterol and lower body mass index (BMI), which is associated with lower blood pressure (Dinu et al., 2017; Key et al., 2006; Radnitz et al., 2020).

The theory of planned behaviour recognises that behavioural intention which is the motivational factors that influence behaviour is the first determinant of whether a behaviour is performed (Ajzen, 1991). Current literature suggests that the three most common motivations for deciding to become vegan are animal ethics, environmental, and health (Ghaffari et al., 2022; Janssen et al., 2016; North et al., 2021). These are commonly mutually inclusive. An observational study of 329 participants by Janssen et al., (2016) identified that 81.8% of individuals are driven by multiple motives. Other less common motives mentioned across numerous studies vary from religion, spirituality, political, and social justice (i.e. human rights, world hunger), to taste, enjoyment, cost, and ease of diet (Ghaffari et al., 2022; Janssen et al., 2016; North et al., 2021). Individuals' motives have also been shown to shift over time. Whilst an individual may become a vegan for one reason, they may also adopt several reasons over time as a result of greater understanding of the impacts of veganism (Beardsworth & Keil, 1991; North et al., 2021). It is assumed by many that animal-related motives will always be part of a vegan's reason for dietary choice, however Janssen et al. (2016) revealed that 10.6% of individuals are not driven by animal-related motives at all. Ghaffari et al. (2022) also propose that veganism is a "philosophy of life" and that through functional (e.g., financial or health) and psychological (e.g., feeling guilt free) benefits it allows vegans to achieve personal self-enhancement and self-transcendent outcomes that subsequently motivate them to continue veganism.

Until now, no studies have been conducted on NZ vegans and what their motivations for choosing to become and remain vegan are.

2.2 Animal ethics as a motivation for veganism

Ethics may be defined as "the discipline dealing with what is good and bad and with moral duty and obligation"(Meriam-Webster, 2023). Ethical reasons for becoming vegan include supporting the rights of animals to reduce exploitation, death, and increase animal welfare. Janssen et al. (2016) demonstrated that animal related motives were the largest determinant of following a vegan diet, with 89.6% of participants stating this motivation. This study revealed consumer attitudes such as "Animals have similar feelings and fears as humans" (86.2% of participants), "all animals should be granted the right to a natural death" (80.2% of participants), and that animal welfare could not be achieved in agriculture at all (50.5% of participants). Although ethical concerns regarding animals is not limited to vegans, it has been demonstrated that vegans hold higher levels of animal welfare values than vegetarians and omnivores (North et al., 2021; Trethewey & Jackson, 2019). A commonly identified quote to describe the empathy and moral guidance of veganism is "The question is not, Can they reason?, nor Can they Talk? but, Can they suffer? Why should the law refuse its protection to any sensitive being?"(Bentham, 1789). This quote suggests that the capacity for suffering should be used as the benchmark for whether animals are treated differently to humans.

In NZ the Animal Welfare Act 1999 sets out the ethical legislation for animal rights. Within the act is a code that states that an "animal's physical, health and behavioural needs" must be met. This is defined as: "proper and sufficient food and water, adequate shelter, the opportunity to display normal patterns of behaviour, appropriate physical handling, protection from, and rapid diagnosis of, injury and disease."(New Zealand parliamentary counsel office, 1999) Although this act has been applauded around the world for its recognition of animals as 'sentient', vegans believe that it is not enough, and that farming of animals in any way results in death, which could have otherwise been avoided (Callister-Baker, 2017).

Considering New Zealand's reliance on meat, eggs, and dairy exportation for economic growth and the typical NZ dinner consisting of *'meat and 3 vege'* one would assume veganism would be slow to gather momentum. However, agricultural companies in NZ have already recognised the threat of veganism to their businesses (Skerrett, 2019). In the past 10 years, the NZ public's interest in animal welfare has risen and as such the government as well as agricultural companies have made major changes to keep consumers happy. These include the banning of battery caged eggs, and more recently the prevention of bobby calf killing. In 2012, the NZ government amended the animal welfare code and gave farmers a 10-year period to phase out battery farming of hens, with it becoming illegal from the 1st of January 2023 (Corlett, 2022). Supermarket chains Foodstuffs and Progressive enterprises have also pledged to the public to become "100% cage free for packaged eggs" by 2027 and 2025, respectively (Nichol, 2017). Secondly, NZ multinational dairy co-operative Fonterra has changed their terms of supply such that as of June 2023, they will no longer accept milk from dairy farms who kill their bobby calves. This purpose for change is reflected in a statement made by the company "We can't afford to be complacent as consumers here and around the world become more interested in how their food is produced" (Mead, 2023). From a business perspective, the implementation of increased animal welfare may be viewed as a means to keep the public consuming animal products, by reducing the cognitive dissonance associated with harming animals. This is incredibly important to the agricultural sector because the dairy and egg industries in NZ bring in approximately $19b and $18m in export revenue each year, respectively (Corlett, 2022).

2.3 The Environment as a motivation for veganism

Environmental motivations for becoming vegan often stem from a place of broad concern for the planet, humanity, and consideration of the consequences of ones actions (Ghaffari et al., 2022). Environmental concerns may be about climate change events, loss of biodiversity and exhaustion of natural resources, as well as the sustainability of our diets for future generations. Worldwide, the production of food from farm to fork produces approximately 25% of the total human generated greenhouse gas emissions, of which approximately 80% of these are attributed to livestock production (Errickson et al., 2021; Poore & Nemecek, 2018; Stehfest et al., 2009). It has also been estimated that by continuing our global dietary habits high in animal products, without change, GHG emissions, crop land use, fresh water use, and nitrogen and phosphorous application may rise between 50% - 90% by 2050 (Willett et al., 2019).

The EAT Lancet commission have outlined several measures to reduce the environmental effects of food production and transition to sustainable food production, of which dietary changes towards healthy diets is one that consumers are able to implement themselves. The reference diet developed by the EAT Lancet commission places an emphasis on increasing protein and fat intake from plant products, and greatly minimising or completely removing intake from all animal products. Although becoming a strict vegan is not necessary to obtain beneficial outcomes for the environment, vegan diets have been associated with the greatest reductions in GHG emissions and land use (Peters et al., 2016; Willett et al., 2019). The commission has estimated that increased consumption of plant-based diets may reduce agricultural GHG emissions by up to 80% by 2050, which indicates that a strict vegan diet may lead to even greater reductions (Willett et al., 2019). Conversely, the EAT Lancet diet for planetary health has recently been reviewed, showing that it does not meet the globally recognized adequate intakes of folate, vitamin A, vitamin B12, calcium, iron, and zinc (Beal et al., 2023). These nutrient deficiencies have been attributed to the increased consumption of wholegrains and foods high in phytates, as well as minimising animal sources that contain highly bioavailable quantities of essential nutrients (Beal et al., 2023).

Until recently, it has been unclear of the role of the environment as a motivator for veganism. However, new studies have revealed that 29.08% - 53.64% of vegans consider the environment as a driver for becoming or remaining vegan (Janssen et al., 2016; North et al., 2021; Ploll & Stern, 2020). This is no longer a surprise given the quantity of research indicating the harmful effects on the environment of a diet high in animal foods. Animal agriculture has three main outcomes that impact the environment. These include increased GHG emissions, increased land use, and increased water use (Aleksandrowicz et al., 2016). Of all animal agriculture, cattle farming for beef has been shown to produce the largest amount of greenhouse gases and use the largest amount of land per kg. Global data shows that on average cattle produce 50 kilograms per carbon dioxide equivalents (kgCO2e) of GHG emissions and use 164m^2 of land per 100g of protein. In comparison, tofu (a vegan protein source), produces 2kgCO2e of GHG emissions and uses 2.2m^2 of land per 100g of protein (Poore & Nemecek, 2018). The increased GHG emissions from meat production is subsequently reflected in GHG emissions of different diets. The EPIC-Oxford cohort study revealed that after adjusting for age and sex, a high meat diet (>100g.day) of 2000kcal created 2.5 times more GHG emissions than a vegan diet of isocaloric value (Scarborough et al., 2014). Per person, a vegan diet results in a reduced carbon footprint of 1,560kgCO2e/year which is equivalent to flying economy from Auckland to Perth and back twice (*Carbon Calculator*, 2023; Scarborough et al., 2014)

The extent to which these global findings apply to NZ are not certain. This is because NZ is unique in that 81% of electricity comes from renewable sources, and that its farming practices are largely grazing based rather than grain fed production systems. Drew et al. (2020) investigated 10 different diets that met the New Zealand dietary guidelines (NZDG's) and the subsequent NZ specific GHG emission estimates. They found that the foods contributing to the highest GHG emissions were beef and lamb, at 21kg and 17kgCO2e, respectively. The lowest producers of GHG emissions were legumes, fruits, vegetables, grains, and cereals all producing between 1.2 – 1.8kgCO2e. It was also found that a typical

NZ diet, that was not currently meeting NZDG's resulted in 6.6kgCO2e per day. In comparison, moving to a vegan diet that met NZDG's resulted in only emitting in 4.42kgCO2e per day, a 33% savings in GHG emissions (Drew et al., 2020). This research reveals that even in the NZ context, using different farming and energy practices, a vegan diet still results in better outcomes for the environment.

It can be concluded that our dietary habits, have the ability to significantly impact the production of greenhouse gas emissions (Whitmee et al., 2015). The consequences of the current food system are likely to impact future food production and availability, choice, nutritional intake, and food safety. This is true in countries where the low food accessibility already exists and where the impacts of climate change are felt first such as the Middle East and African nations (Springmann et al., 2018; Willett et al., 2019).

2.4 Health as a motivation for veganism

There is growing evidence that a vegan diet has multiple health benefits such as being cardioprotective, decreasing the risk of certain cancers, and preventing the development of type 2 diabetes mellitus (Davey et al., 2003; Dinu et al., 2017; Key et al., 2006; Radnitz et al., 2020; Wegmüller et al., 2017). Conversely, a vegan diet can also have negative health consequences such as increased risk of osteoporosis due to decreased calcium intake, and deficiencies in omega-3 fatty acids, vitamin D, vitamin B12, iron and zinc (Key et al., 2006; Smith, 2006). Although a vegan diet is considered to be rich in fruit, vegetables, and plant foods, due to the technological advancements of the food industry, many ultra processed foods high in fat, salt, and sugar are also now being produced for the vegan market (Gehring et al., 2021; Young et al., 2023). This raises the question of whether the health benefits of a vegan diet are still applicable if a large proportion of the vegan diet comes from ultra processed foods.

In an Australian study comparing the dietary motives of vegans, vegetarians and omnivores, 50.67% of vegans mentioned health as a motivator (North et al., 2021). A similar level of health as a motivator amongst vegans (47%) has also been found by Dyett et al. (2013). However, health as a motivator has been found to be as high as 69.3% and 71.91% in other studies (Janssen et al., 2016; Marciniak et al., 2021). Of interest is that North et al. (2021) found participants of all dietary groups frequently said health was a motivator for their diet choice. Other studies have also found that the motive of health for dietary choice has not significantly differed between diet groups, suggesting that health is always contemplated when deciding one's diet and is not an exclusive motivator for veganism (Haverstock & Forgays, 2012; Trethewey & Jackson, 2019). Participants in a study by Ghaffari et al. (2022) disclosed that veganism allowed them to maintain control of their health, which lead them to the functional benefit of being able to achieve their daily tasks. North et al. (2021), expands on this and reveals that "health" was perceived and validated differently between dietary groups. For example, whilst all three groups mentioned personal health, there was a theme that vegans believed that their diet extended further than their own health and was a diet that benefited the health of others, and the planet as a whole. This complementary evidence demonstrates the potential for health motivations to be driven either by the goal of personal wellbeing and self-enhancement or self-transcendent outcomes.

Drew et al. (2020) also considered the health gains and healthcare systems cost savings if individuals were to move from a typical NZ diet, that was not currently meeting NZ Ministry of Health eating and activity guidelines to a vegan diet that met the guidelines. They found that a vegan diet would result in 43% higher quality adjusted life years (QALY's), equivalent to 1.46million QALY's added over the lifetime of the NZ population in 2011. A vegan diet would also lead to healthcare systems cost savings of 45%, equivalent to $20.2 billion NZD saved over the lifetime of the NZ population in 2011. This singular study highlights the potential impact of moving to a vegan diet, however its findings are limited as no other studies have confirmed similar outcomes in a NZ scenario.

Contrary to expectation, Radnitz et al. (2015) demonstrated that vegan individuals who were motivated primarily by health consumed significantly less soy-based foods, foods high in vitamin D, and sweets per month and were less likely to consume multivitamins, vitamin D or vitamin B12 supplements than individuals motivated by ethical reasons. There were no significant differences in consumption of vegetables, foods high in polyphenols, or foods high in omega-3 and omega-6 fatty acids between groups. No other studies have investigated the relationship between health as a motivator and dietary intake within the vegan population.

2.5 Nutrients of concern

Following a vegan diet can lead to inadequate intakes of key nutrients such as vitamin B12, iron, long chain omega-3 fatty acids, vitamin D, vitamin A, calcium, zinc, iodine, and protein (Bakaloudi et al., 2021; Davey et al., 2003; Key et al., 2006). This is primarily because foods containing high bioavailable sources of these nutrients are of animal origin and are therefore removed when individuals transition to a vegan diet (Craig, 2009). However, with adequate diet planning and supplementation with these key micronutrients, vegans are able to meet their nutritional needs and maintain satisfactory health outcomes (Academy of Nutrition and Dietetics, 2003). Unfortunately meeting one's nutritional requirements is not always top priority. Due to the varying motivations for choosing a vegan diet, individuals may display a lack of interest in nutrition or have poor nutrition knowledge and therefore be unable to plan their diet to meet their physiological needs.

2.6 Vitamin B12

Vitamin B12 is involved in the production of DNA, red blood cells, and neurotransmitters. Chronic low dietary intake and subsequent deficiency of vitamin B12 can therefore lead to neurological as well as haematological consequences such as anaemia. It can also impact the metabolism of folate, leading to high concentrations of homocysteine in the blood, which is known to be a risk factor for cardiovascular diseases (Avinash et al., 2017; Pawlak, 2015).

Vitamin B12 is usually only able to be obtained in adequate amounts from animal products. This is because there are very few plant sources that can contain enough vitamin B12 in its active form to contribute to intake requirements (Fumio et al., 2014). Blue-green algae such as spirulina (cyanobacteria) were once thought to be a reliable source of vitamin B12, however research has proven that these products contain mostly (83%) pseudo-vitamin B12, which is inactive in humans and can also inhibit the absorption of genuine vitamin B12 (Watanabe et al., 2013; Žane Temova Rakuša, 2022).

There are plant sources of vitamin B12 that do contain the active form of vitamin B12. Certain types of mushrooms have been identified to contain the active form such as dried shitake (Lentinula edodes), golden chanterelle (Cantharellus cibarius), and black trumpet (Craterellus cornucopioides), however the concentration available varies significantly and the volume required to be consumed to meet the recommended dietary intake (RDI) exceeds 500g of fresh mushrooms per day, making this unfeasible. Fermented beans and vegetables such as tempeh, kimchi and tea have also been found to contain the active form of vitamin B12 however due to the concentration relying on the type of bacteria used to ferment these products and different processing techniques, concentrations vary and as such they cannot be considered a reliable source (Fumio et al., 2014). The only plant sources that are a good source of active vitamin B12 are two genera of algae; dried green laver (Enteromorpha sp.) and purple laver (Porphyra sp.). These genera have been found to contain between 32.3µg.100g dry weight and 133.8µg.100g dry weight, respectively (FSANZ, 2017; Fumio et al., 2014; Miyamoto et al., 2009). Although these algae are widely consumed around the world, manufacturers rarely state the genus making it difficult to plan dietary intake.

Bioavailability of B12 is largely dependent on quantity consumed, and the food or supplement source. As the quantity consumed increases, absorption decreases. For example, 80% of a 0.1µg dose is estimated to be absorbed, compared to 50% of a 1µg dose, and 5% of a 25µg dose (Žane Temova Rakuša, 2022). Unlike vitamin B12 that is bound to protein in food, vitamin B12 supplements contain a free form of the vitamin which is more readily absorbed as it does not require release from food proteins by gastric fluid (Žane Temova Rakuša, 2022). In healthy adults, the average amount of vitamin

B12 stored in the body is between 2-3mg, of which over half is stored in the liver. Each day 0.5 – 5.0µg of vitamin B12 is secreted in the bile, however 50 - 80% is then re-absorbed in the ileum (Allen et al., 2018; Žane Temova Rakuša, 2022). These pathways are the reason why in healthy adults, vitamin B12 deficiency can take years to become apparent, even in the absence of intake. For women and men aged 19 years and older, the RDI of vitamin B12 is 2.4µg.day, based on an estimated average absorption of 50% from food (Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017).

Fortunately, over-the-counter vitamin B12 supplements are widely accessible and affordable. The four most common vitamin B12 corrinoid compounds used in supplements and food fortification are methylcobalamin (MeCbl), cyanocobalamin (CNCbl), 5'-deoxyadenosylcobalamin (AdoCbl), and hydroxocobalamin (OHCbl). All four compounds have been found to be comparable in terms of bioavailability (Obeid et al., 2015). Absorption of vitamin B12 used in supplements and added to fortified foods is estimated to be slightly higher than food sources, at 60% (Allen et al., 2018).

Due to the recognition of low intakes of vitamin B12 in a vegan diet and its importance for maintaining health, vitamin B12 has become a micronutrient that is commonly used to fortify plant-based meat and dairy analogues (PBMDA). In NZ and Australia, the maximum allowed addition of vitamin B12 to food ranges between 0.2µg to 2.0µg depending on the type of food (FSANZ, 2021). However, the actual quantity of fortification within this range is decided by the manufacturer, demonstrating how much planning must go into choosing fortified foods with adequate fortification to meet requirements (FSANZ, 2021). Foods commonly fortified with vitamin B12 are yeast extracts, nutritional yeasts, fortified cereals, and PBMDA.

One study has investigated whether adherence to supplementation of vitamin B12 or duration of vegan diet has an effect on plasma vitamin B12 levels (Selinger et al., 2019). They found no significant differences in diet duration and plasma vitamin B12 levels. However, the highest occurrence of low plasma vitamin B12 levels (based on vitamin B12 < 190ng.L) were found amongst short term (<3 years) vegans (28.2%) and long term (>7 years) vegans (17.1%) compared to mid-term (3-7 years) vegans (4.55%). After adjusting for diet duration they found significantly lower plasma vitamin B12 levels amongst non-supplementers and irregular supplementers compared to regular supplementers. This study shows that without supplementation of vitamin B12, a vegan diet leads to poor vitamin B12 status, after adjusting for diet duration (Selinger et al., 2019).

Few studies have considered how motivation for following a vegan diet may affect intake of nutrients. Dyett et al. (2013) found no significant difference in the intake of vitamin B12 amongst vegans motivated by health, animal welfare, or religious and other. However, only 51% of vegan participants met the estimated average requirement (EAR).

2.7 Omega-3 fatty acids

There are three main types of omega-3 fatty acids present in foods. These are alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are all long-chain omega-3 fatty acids (Raymond, 2020). ALA is considered an essential omega-3 fatty acid and must be supplied from the diet as humans are unable to synthesise it (Raymond, 2020). Sources of ALA are mostly plant based such as chia and hemp seeds, walnuts, flaxseeds, avocado, canola and soybean oils. Conversely, EPA and DHA are primarily found in seafood, with high concentrations in fatty fish such as salmon, mackerel, tuna, and sardines (Lane et al., 2022; Meyer et al., 2003). However, EPA and DHA can also be found in certain species of algae and seaweed, which are the only plant sources (van Ginneken et al., 2011).

Although ALA, EPA and DHA are all omega-3 fatty acids, they all play different roles in the body. The current research is inconclusive about the definitive role of ALA, as it is primarily used as a precursor to EPA and DHA. However, studies have shown higher intakes in ALA lead to a beneficial reduction in atherogenic lipids and lipoproteins, blood pressure, and inflammation markers (Lane et al., 2022; Sala-Vila et al., 2022). EPA and DHA play a critical role in the formation of cell membrane structure, signalling molecules as well as gene expression and reducing inflammation (Larsson et al., 2004; Swanson et al., 2012; Tortosa-Caparrós et al., 2017). DHA also plays a crucial role in developing the brain, retina and central nervous system (Carlson et al., 2013). Overall, adequate intake of EPA and DHA has been shown to be protective against developing CVD, some cancers, and Alzheimer's disease (AD) (Cederholm et al., 2013; Larsson et al., 2004; Tortosa-Caparrós et al., 2017). Conversely, inadequate intake has been linked to poor cardiovascular health, and an increased risk of developing AD (Cederholm et al., 2013; Heude et al., 2003; Tortosa-Caparrós et al., 2017).

When consumed, ALA is metabolised via multiple steps of desaturation and elongation to form EPA. EPA must then undergo further desaturation, elongation, and oxidation to form DHA (Carlson et al., 2013). The conversion of ALA to EPA and DHA is very limited with studies showing between 0.01-10% of ALA is able to be converted (Goyens et al., 2005; Swanson et al., 2012). Therefore, production of enough EPA and DHA to meet physiological needs may not be practical from consumption of ALA alone. Although algae and seaweed are plant sources of EPA and DHA, the concentration is very low and differs widely between species. For example consuming a 5g serving of dried algae (*P. palmata*) would provide only 0.04g of EPA and no DHA (van Ginneken et al., 2011). Algal oil supplements containing

600mg DHA have been shown to be as effective as 600mg DHA provided through salmon fillets, with no significant differences in increased plasma and erythrocyte concentrations of DHA (Arterburn et al., 2008). Although algal oil has been demonstrated as a viable method of increasing DHA levels in the blood of vegans and vegetarians, appropriate dosing is yet to be determined for optimal nutritional status (Craddock et al., 2022; Lane et al., 2022; Rosell et al., 2005; Sanders, 2009).

In NZ the recommended daily intake of ALA, EPA and DHA for adults aged 19 years and older varies by sex, with women being able to convert a greater amount of ALA to EPA and DHA than men (Burdge & Calder, 2005). For women the adequate intake (AI) of ALA is set at 0.8g.day and the AI of EPA and DHA combined is set at 90mg.day. For men the AI of ALA is set at 1.3g.day and the AI of EPA and DHA is set at 160mg.day (Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017).

One common test used as a biomarker of omega-3 intake is the omega-3 index (Harris, 2007). The index measures the sum of EPA and DHA within erythrocyte membranes which is represented as a percentage of total erythrocyte fatty acids. Although the index cannot differentiate between EPA and DHA levels, it provides an insight into an individual's omega-3 status which subsequently be used as a marker and risk factor for coronary heart disease. Current research denotes that a cardioprotective target value is >8%, with values between 4-8% being an intermediate risk factor, and values <4% a high-risk factor (Harris, 2007, 2008).

2.8 Iron

The main role of iron is to be a component of haemoglobin, a protein in the blood which transports oxygen around the body (Raymond, 2020). Inadequate intake of iron can therefore result in inadequate haemoglobin production and decreased oxygen distribution in the body. Iron is also essential for adenosine triphosphate (ATP) production, electron transport and gene expression (Boldt, 1999; Clark, 2008). Depending on the level of deficiency, symptoms such as fatigue, shortness of breath, weakness, and pale appearance may occur (Clark, 2008). With severe deficiency, iron deficiency anaemia (IDA) may result. The causes of iron deficiency are multifactorial, such that it may occur due to inadequate intake, decreased absorption capacity, impaired transport, increased requirements, or increased losses (Clark, 2008). A vegan diet is more likely to result in iron deficiency, due to increased risk of inadequate intake and decreased bioavailability of iron found in plants (Bakaloudi et al., 2021).

The bioavailability of iron is dependent on a variety of factors such as type (haem vs non-haem), dose, body stores, and intake of iron inhibitors and enhancers (Hunt, 2003). Animal products such as meat, fish and poultry contain a combination of both haem (~40%) and non-haem (~60%) iron, however plant products only contain non-haem iron (Hunt, 2003). Haem iron is more bioavailable with between 15-40% estimated to be absorbed, whereas only 1-15% of non-haem iron is estimated to be absorbed (Hunt, 2003).

Absorption of iron is tightly regulated by the body as there are no mechanisms for excretion. The peptide hepcidin has been identified as the key regulator of iron stores, such that when iron stores are high, hepcidin concentrations increase, preventing absorption of iron. Hepcidin concentration also increases after a meal high in iron, thus preventing the absorption of iron in the hours following (Ganz & Nemeth, 2006).

Iron inhibitors include calcium and zinc, phytates and oxalates found in wholegrains, legumes, nuts and seeds, as well as tannins and polyphenols found in tea, coffee, cocoa, and wine (Hurrell & Egli, 2010). On the other hand, enhancers of non-haem iron absorption include haem iron rich foods such as meat, fish, and poultry (MFP) factor, ascorbic acid, fermented foods, prebiotics, as well as citric and organic acids (Scheers et al., 2016; Teucher et al., 2004). Plant sources of iron include legumes such as kidney beans, chickpeas, and lentils, pumpkin seeds, hemp seeds, spinach, dried apricots, tofu, tempeh, and oats (New Zealand Food Composition Database, 2022). Many cereals and PBMDA may also be fortified with iron, meaning that with considerable effort and planning it is possible to consume adequate iron while following a vegan diet (Academy of Nutrition and Dietetics, 2003; New Zealand Food Composition Database, 2022).

Although it is possible to consume equal quantities of dietary iron from a vegan diet as one can from an omnivorous diet, the quantity of iron-rich foods needed to be consumed is much greater (Academy of Nutrition and Dietetics, 2003; Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017). Currently, it is recommended for vegetarians and vegans to consume 80% more dietary iron than omnivores to compensate for a lower average estimated bioavailability of 10%, in comparison to the estimated average bioavailability of 18% in omnivores (Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017). In NZ the RDI of iron for men and women between the age of 19 – 50 years of age differs, due to women experiencing increased iron losses from their menstrual cycle. For women the RDI is set at 18mg.day, and for men the RDI is set at 8mg.day (Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017).

In one study investigating the relationship between iron intake and motivation type, no significant difference was found between vegans motivated by animal welfare, health or religious and other and intake of iron (Dyett et al., 2013). There have been no New Zealand studies investigating this relationship.

2.9 Summary

The factors that motivate New Zealand vegans to become and remain vegan are unknown, let alone how their type of motivation may influence dietary behaviours and therefore nutrient intake and nutritional status. Knowledge of how motivation type impacts nutrition is especially important in veganism where omission of all animal products requires a significant level of motivation already. As the vegan diet is inadequate in many nutrients key to important physiological functions, it is important to understand whether New Zealand vegans have poor nutrient intake or nutrient deficiencies, and subsequently whether those motivated by health have better nutrient intake and nutritional status.

Chapter 3: Manuscript

3.0 Abstract

Background: Animal ethics has always been a primary motivator for veganism. Nowadays, the environment and health are also increasingly common motivators. Omission of animal products leads to intake of low bioavailable iron, exclusion of vitamin B12, and limited intake of omega-3 fatty acids.

Objectives: To describe the importance placed on three motivations for following a vegan diet, to investigate the role of health on dietary intake of vitamin B12, iron and the nutritional status of omega-3 fatty acids, vitamin B12, and iron, as well as investigate the role of health motivation on use of vitamin B12, iron and omega-3 supplementation.

Methods: This cross-sectional, observational study recruited participants, who had followed a vegan diet for minimum 2 years. Demographics were obtained from questionnaire. Motivation type was determined using the validated vegetarian eating motives inventory (VEMI) – participants scored the importance of animal ethic, environment and health. Dietary intakes of vitamin B12 and iron, were calculated from a 4-day food diary and assessed against the Estimated Average Requirement (EAR). Blood samples were taken to determine status of vitamin B12, haemoglobin, serum ferritin, and omega-3 index.

Results: 212 participants, 73% female, with mean (SD) age of 39.43 years (12.41) completed the study. Animal ethics was a very important motivator for 83.5% of participants, compared to the environment (71.7%), and health (53.3%). Participants motivated the greatest by health had significantly higher intake of iron ($p = 0.032$) and lower intake of vitamin B12 ($p = 0.006$) after adjusting for energy intake. No relationship was found between health motivation and omega-3 index. Participants used omega-3 fatty acid, iron and B12 supplementation regardless of level of health motivation. Mean serum ferritin (41.62µg.L), haemoglobin (154.31g.L), and vitamin B12 (316.54pmol.L) were adequate. The mean omega-3 index was 3.15%, with no participants having a cardioprotective score of >8%.

Conclusion: The motivation of health appears to influence intake of iron and vitamin B12. Vitamin B12 status within normal range, despite not meeting the EAR and limited vegan sources, indicates the use and importance of supplementation. Iron status shows large consumption of iron rich foods to overcome bioavailability issues. Omega-3 index reveals low cardioprotective omega-3 fatty acid intake.

3.1 Introduction

Veganism was first defined in 1944 by a man named Donald Watson. Although the definition of veganism has changed slightly between decades, its main message has remained the same – to as much as possible avoid the exploitation and harm to animals (The Vegan Society, 2023). With increased dissemination and access to knowledge about the exploitation, killing methods, and living conditions of farmed animals, the number of people reducing their meat intake and are on the path to becoming vegan has increased rapidly. Research conducted in New Zealand (NZ) shows that in 2022 19% of New Zealanders either "always" or "mostly" eat vegetarian or vegan compared to 10% in 2018 (Kantar, 2022). However, in NZ, a country that's economy is driven by the exportation of animal's products, such as milk powder, eggs, and meat, little is known about the individuals who follow a vegan diet, such as why they chose to become vegans, and what their health status is.

The three main motivations for following a vegan diet are ethics, environmental, and health. Other motivations also exist such as religion and spirituality, taste and enjoyment, political and social justice, as well as the ease of diet (Ghaffari et al., 2022; Janssen et al., 2016; North et al., 2021)., Individuals are commonly motivated by multiple reasons to become vegan, with few individuals citing a singular motivation, reflecting how complex motivation can be (Janssen et al., 2016).

Ethical motivation may be considered the original incentive for those who began the vegan movement as their purpose was "to seek an end to the use of animals by man for food, commodities, work, hunting, vivisection, and by all other uses involving exploitation of animal life by man" (The Vegan Society, 2023). More recently it has been identified that ethical motivations remain the greatest drive for following a vegan diet (Janssen et al., 2016; North et al., 2021; Ploll & Stern, 2020; Radnitz et al., 2020). Although ethical motivations are not restricted to vegans it has been shown that vegans have higher animal welfare values than omnivores and vegetarians (North et al., 2021; Trethewey & Jackson, 2019). Common attitudes expressed by vegans are "Animals have similar feelings and fears as humans" and that "all animals should be granted the right to a natural death" (Janssen et al., 2016).

It has long been known that animal agriculture produces large amounts of greenhouse gas emissions, requires vast quantities of land, water and food, as well as energy to grow, slaughter and preserve the meat and its byproducts (Aleksandrowicz et al., 2016; Poore & Nemecek, 2018). For many years these problems have been overlooked and it is not until recently that their cumulative effects have shown to be catalysts of climate change (Poore & Nemecek, 2018; Willett et al., 2019). With increasing consciousness on the need to slow down climate change, individuals have used the vegan diet as a means to take responsibility into their own hands. The Eat Lancet commission has estimated that transitioning the world's population to a plant-based diet could decrease GHG emissions by up to 80%

by 2050, with even further increases by following a vegan diet (Willett et al., 2019). It has also been shown that a vegan diet produces 2.5 times less GHG emissions than an omnivore diet containing >100g meat per day (Scarborough et al., 2014).

Health is a common motivator for being vegan, with between 47 - 71.91% of vegans citing it as a reason for becoming and remaining vegan (Dyett et al., 2013; Marciniak et al., 2021). However, what individuals perceive to be a healthy diet varies considerably, and it is a motivator that is not only exclusive to vegans (North et al., 2021; Trethewey & Jackson, 2019). Although a vegan diet is considered to be rich in plant wholefoods, it has also been unable to avoid the rise in development of ultra-processed foods, with many plant-based meat and dairy analogues and snacks falling into this category (Gehring et al., 2021). Therefore, the perceived healthiness and health benefits gained from a vegan diet are only as good as the vegan food consumed. In the NZ context, adopting a vegan diet that followed the NZ Ministry of Health eating and activity guidelines would result in 43% higher quality adjusted life years (QALY) for adults, equivalent to 1.46 million QALY as well as $20.2 billion NZD in healthcare system cost savings over the lifetime of the NZ population in 2011 (Drew et al., 2020).

The vegan diet has been both applauded and placed under heavy scrutiny, especially within the past few years as researchers attempt to understand how completely removing animal products from a diet may impact or improve health. On one hand, the vegan diet has been shown to result in improved cardiovascular health through lowered blood pressure, LDL and total cholesterol levels, as well as decreased risk of developing type 2 diabetes and cancer (Dinu et al., 2017; Key et al., 2006; Radnitz et al., 2020). On the other hand, it has been shown to be deficient in vital nutrients, that can subsequently lead to poor bone health, immune function, energy levels, and overall suboptimal nutrient status (Key et al., 2006; Smith, 2006). Nutrients that are difficult to achieve adequacy of in a vegan diet are vitamin B12, iron, omega-3 long chain fatty acids, zinc, calcium, vitamin D, vitamin A, iodine, and protein (Bakaloudi et al., 2021; Davey et al., 2003; Key et al., 2006). This is commonly due to a combination of poor bioavailability and decreased concentration of these nutrients from plant sources (Bakaloudi et al., 2021).

Vitamin B12 plays an important role in the production of red blood cells, DNA, and neurotransmitters. Therefore, inadequate intake and subsequent deficiency can result in both haematological and neurological consequences (Avinash et al., 2017; Pawlak, 2015). Vitamin B12 is a nutrient that is typically found in high concentrations in wide variety of animal foods but very low concentrations in very few plant foods (Fumio et al., 2014). Nevertheless, certain genera of algae; dried green laver (Enteromorpha sp.) and purple laver (Porphyra sp.), have now been shown to contain high concentrations of vitamin B12 that could contribute to obtaining adequate intake (Fumio et al., 2014; Miyamoto et al., 2009). Blue-green algae, widely known as spirulina was once thought to contain genuine vitamin B12, however it is now understood that it is mostly pseudo-vitamin B12, an inactive form that actually inhibits the absorption of genuine vitamin B12 (Watanabe et al., 2013; Žane Temova Rakuša, 2022). The bioavailability of vitamin B12 is dependent on the quantity consumed, and the food or supplement source. The vitamin B12 from supplements is in a free-form, making it more readily absorbed than vitamin B12 bound within the food matrix that requires release by gastric fluid. As the quantity of vitamin B12 within a meal increases, the absorption decreases such that 80% of a 0.1ug dose is estimated to be absorbed, compared to 50% of a 1ug dose, and 5% of a 25ug dose (Žane Temova Rakuša, 2022). Fortunately, there are now hundreds of over-the-counter vegan friendly vitamin B12 supplements available to buy as well as plant-based meat and dairy analogues that have been fortified with vitamin B12 in response to the increased risk of vitamin B12 deficiency amongst vegan and vegetarian populations.

The three main types of dietary omega-3 fatty acids are alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). ALA is considered an essential fatty acid and must be obtained through our diet as our bodies cannot synthesise it (Raymond, 2020). It is primarily used as a precursor for EPA and DHA production although its synthesis is limited, with research showing only 0.1 – 10% is able to be converted (Goyens et al., 2005; Swanson et al., 2012). High intake of ALA has been shown to decrease atherogenic lipids, reduce blood pressure, and inflammation (Lane et al., 2022; Sala-Vila et al., 2022). EPA and DHA are especially crucial for forming the structure of cell membranes and signalling molecules, as well as regulating gene expression (Larsson et al., 2004; Swanson et al., 2012). Adequate intakes of both EPA and DHA have been shown to protect against cardiovascular disease, some cancers, and Alzheimer's disease (Cederholm et al., 2013; Larsson et al., 2004; Tortosa-Caparrós et al., 2017). There are a wide variety plant foods containing ALA such as walnuts, chia and hemp, and flaxseeds, avocado, canola, and soybean oils. However, the main sources of EPA and DHA are animal foods, primarily fatty fish such as salmon, sardines, tuna, and mackerel (Lane et al., 2022; Meyer et al., 2003). The only known plant source of EPA and DHA is certain species of algae, which is not available to purchase for the average consumer (van Ginneken et al., 2011). Due to the limited conversion of ALA to EPA and DHA, meeting the physiological requirements of EPA and DHA may be impractical through consumption of ALA alone (Goyens et al., 2005; Swanson et al., 2012). Therefore, consuming an algae supplement, which is shown to be as effective as salmon at raising blood EPA and DHA levels, may be necessary to meet needs (Arterburn et al., 2008). A commonly used to test to understand an individual's omega-3 status is the omega-3 index. The index measures total

EPA and DHA concentrations within erythrocyte membranes, which can be used as a marker and risk factor for coronary heart disease (Harris, 2007, 2008).

One of the most important roles of iron is that it is a component of haemoglobin, a protein in our blood that carries oxygen in the blood around our body (Raymond, 2020). Iron also plays essential roles in electron transport, energy production, and gene expression (Boldt, 1999; Clark, 2008). Chronic inadequate iron intake can subsequently lead to fatigue, poor immunity, weakness, and paleness (Clark, 2008). It has been shown that vegetarians and vegan are able to consume as much iron from plant foods as omnivores are able to consume from inclusion of animal products (Academy of Nutrition and Dietetics, 2003). However, plant foods contain non-haem iron which is estimated to have a bioavailability of between 1 - 15%, meaning that very little of the iron consumed from plant sources is actually absorbed (Hunt, 2003). This is compared to an estimated 15 - 45% bioavailability of haem iron found in animal products (Hunt, 2003). There is a wide variety of plant sources of iron including spinach, legumes such as red kidney beans, chickpeas, and lentils, pumpkin seeds, dried apricots, tofu, tempeh, and oats (New Zealand Food Composition Database, 2022). However, many of these sources are also high in phytates and oxalates which inhibit the absorption of non-haem iron (Hurrell & Egli, 2010). Other foods components such as calcium and zinc, as well as tannins and polyphenols found in tea, coffee, and cocoa and wine are also inhibitors of non-haem iron absorption (Hurrell & Egli, 2010). Conversely, there are food components known to enhance non-haem iron absorption such as ascorbic acid, fermented foods, prebiotics, as well as citric and organic acids (Scheers et al., 2016; Teucher et al., 2004). To account for decreased bioavailability of iron from plant sources, it has been recommended that the intake requirements of vegetarian and vegan individuals are increased by 80% (Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017).

Although there is now a reasonable amount of research regarding the effects of a vegan diet on nutrient intake and status as well as the main motivations for becoming vegan. There is a lack of research linking the two areas of knowledge. It is known that motivation plays an enormous role in the determining behaviour, and hence it is important we understand how health as a motivating factor impacts food consumption and subsequent nutrient intake and status. Therefore, the aim of this study is to determine the relationship between the motivation of health for being vegan and the intake of key nutrients and nutritional status in individuals following a vegan diet.

3.2 Methods

3.2.1 Study design

A cross-sectional, observational study investigating the importance of the motivation for health for being vegan in relation to intake and status of key nutrients of concern, specifically vitamin B12, iron, and omega-3 fatty acids in NZ individuals following a vegan diet.

3.2.2 Participants and recruitment

Participants were recruited between July and December 2022, through advertisement on social media, community noticeboards, vegan cafes, and word of mouth. The participants in this study were recruited as part of the vegan health research programme at Massey University. Participants included in the study were women and men aged ≥18 years that have followed a vegan diet for at least 2 years. Prior to participation in the study, written informed consent was provided by the participants for themselves to participate.

Ethical approval was provided by the Health and Disability Ethics Committee (HDEC): HDEC 2022 EXP12312.

3.2.3 Data collection

Participant information was collected via an emailed link to the online survey tool, Qualtrics™, or via phone call. An Eligibility Questionnaire was then completed to ensure participants met the inclusion criteria. Eligible participants visited the Human Nutrition Research Unit at Massey University in Auckland where a Massey University Research Assistant took anthropometric measures, using a stadiometer to measure height and electronic scales to measure weight. A Health and Demographic Information questionnaire (Appendix 3) was used to collect demographic data including age, gender, sex, education level, ethnicity, previous diagnosis with iron deficiency, and whether individuals took vitamin B12 injections. Education levels were collapsed to increase the number of participants in each category and increase the effect size. “Lower than High-school”, “High School” and “Diploma/Certificate” were collapsed into “Lower than Bachelor”. “Bachelor’s degree” remained as “Bachelor’s degree”. Then “Master’s degree” and “Doctoral level” were collapsed into “Postgraduate degree”.

To understand personal motivations for adopting a vegan diet, the validated Vegetarian Eating Motives Inventory (VEMI) (Hopwood et al., 2020) was used (Appendix 4). The VEMI has been shown to reliably distinguish between health, environmental, and animal rights motives (the three most reported motives) for plant-based diets. It has been shown to be internally consistent and has robust factor structure, meaning that the relationship between the VEMI questions and motive types are strong.

Participants answered 15 questions on the importance of animal ethics, environment and health for excluding meat and animal products from their diet on a Likert scale of 1-7. Scores for each category were added together then averaged to get the individual's final score. Other motivations such as cultural/religious beliefs, allergy/intolerance to animal-based foods, and having a vegan partner, family, friend, classmate, or co-worker colleague were also assessed using the same Likert scale as the VEMI. Following the participants visit to the Human Nutrition Research Unit each participant completed a 4-day Food Diary (4DFD), with one day being a weekend day and the other three being weekdays. Participants were advised to record the brands of all food and drink, whether the food/drink was cooked or raw, as well as record any information that indicated the portion size eaten, whether that be weight, cup measurements, numbers, or photos. The food diaries were then entered following a set of codebook instructions by MSc Dietetics Students and the Research assistant, into FoodWorks to be analysed for nutritional composition. Vegan food products not found on the FoodFiles 2018 database were entered as a 'New - Food', where ingredients were entered following the percentage stated on the ingredients list and macronutrients adjusted to replicate the nutritional information panel. Recipes outlined in the food diaries were entered into FoodWorks as a 'New – Recipe' using the quantities provided by the participant. The same Students and Research assistant reviewed all food diaries after entry as well as any recipes and new commercial foods entered into the database. If food diaries indicated consumption of animal foods, the diaries were removed from FoodWorks and all other participant data was removed from the study. The FoodWorks database indicated that spirulina was providing high levels of vitamin B12 in participants diets. However, as vitamin B12 from spirulina is known to be pseudo-vitamin B12 which acts as an inhibitor to genuine vitamin B12 absorption, (Watanabe et al., 2013; Žane Temova Rakuša, 2022) the vitamin B12 from spirulina was changed to zero. Supplementation habits were assessed in the Dietary Practices and Supplement Use questionnaire (Appendix 4). To determine supplement use, participants must have been using specific supplements at least once per week to be counted. Vitamin B12 injections were not counted as supplementation.

Mean intake of vitamin B12, iron, and omega-3 fatty acids were assessed, including supplements. The study used the Nutrient Reference Values (NRV's), including the estimated average requirement (EAR) for Australian and New Zealand adults, as norms for individual nutrient intake. Results were converted to percentage of age specific-EAR for iron and vitamin B12. For this study, 'inadequate intake' was defined as <100% of the EAR. The biochemical indices used to indicate adequacy of vitamin B12 were 170 – 600pmol.L, values <170pmol.L indicated deficiency. Haemoglobin and serum ferritin were used as biochemical indicators of iron deficiency. The Hb range used for men was 130-175g.L and >120g.L for non-pregnant women. The World Health Organization (WHO) serum ferritin cutoff for iron deficiency used was <15µg.L for adults aged 20 – 59 years. The omega-3 index was used as the biochemical indicator of omega-3 status. Values >8% indicated a cardioprotective omega-3 status, with values between 4-8% indicating an intermediate risk factor, and values <4% a high-risk factor for coronary heart disease. To categorize participants into low, medium, and high levels of health motivation, participants health motivation scores were ordered from lowest to highest and split into tertiles.

3.2.4 Blood sampling and analysis

Venous blood was drawn by a qualified phlebotomist. One drop of whole blood was then dropped onto a dried blood spot card (ensuring that blood completely filled a circle) for the analysis of fatty acids. The blood spot was allowed to dry at room temperature for 15mins then the sample was stored in the sample card in a plastic bag in the freezer at 20℃ until ready to be sent for analysis. The remaining venous blood was then centrifuged at 4℃ at 3500rpm for 15minutes. Serum was then separated into aliquots (2 x 4ml) and stored at -80℃ until ready to be sent for analysis. Blood samples were sent to Canterbury Health Labs (& North shore) for analysis of vitamin B12 and iron studies. Dried blood spot samples were sent to OmegaQuant Analytics for analysis of omega-3 fatty acids.

3.2.5 Statistical analysis

All statistical analyses were conducted using SPSS Statistics, version 27.0; SPSS Inc., Chicago, IL. Normality of distribution was evaluated using normality plots and Kolmogorov-Smirnov tests. The population was described using mean and standard deviation (SD) for normally distributed data, or number of participants and percentage for categorical data. *p-value* used was 0.05.

To compare the numerical data differences between two groups e.g. sex, independent t-test or Wilcoxon rank sum test was used. To compare the numerical data differences between three groups e.g. low, medium, high in Health Motivation score, Kruskal-Wallis rank sum test was used. To compare categorical differences between two (or three) groups Fishers exact test or Pearsons Chi-Squared test was used. For all tests a *p*-value <0.05 was considered statistically significant. Correlations between importance of health motivation and participant variables were determined using Pearson's correlation. Multiple linear regression using the enter method was used to understand the impact the independent variables (animal motivation, environment motivation, health motivation, education, vitamin B12 or iron supplementation, age, and sex) had on the variance of iron and vitamin B12 intake after adjustment for energy intake.

3.3 Results

3.3.1 Participants

Two-hundred and twelve participants provided blood samples for analysis, of which all were analysed. One-hundred and eighty-seven participants completed the four-day food diary, and six participants completed a three-day food diary.

The mean age of participants was 39.43 years. Most participants identified as being European ethnicity (85%) and had education of a bachelor's degree or above (69%). Significantly more women had previously been diagnosed with iron deficiency (45%), compared to men. A similar number of participants had been vegan for 2-4 years and 5-10 years (Table 3.1).

Table 3.1: Participant characteristics (n = 212)

Characteristic	Overall n = 212[1]	Male n = 57[1]	Female n = 155[1]	*p-value*
Age (years)	39.43 (12.41)	40.12 (12.11)	39.18 (12.55)	0.55[2]
BMI (kg.m²)	23.92 (3.11)	24.48 (2.97)	23.71 (3.15)	0.080[2]
Length of time being vegan				0.51[3]
2 – 4 years	84 (39.6%)	22 (38.6%)	62 (40.0%)	
5 – 10 years	43 (43.9%)	28 (49.1%)	65 (41.9%)	
>10 years	35 (16.5%)	7 (12.3%)	28 (18.1%)	
Ethnicity				0.11[3]
European	178 (85%)	50 (88%)	128 (84%)	
Māori	8 (3.8%)	0 (0%)	8 (5.2%)	
Pacific people	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%)	
Education				**0.002[3]**
Lower than Bachelor	66 (31%)	22 (46%)	40 (26%)	
Bachelor's degree	96 (45%)	15 (26%)	81 (52%)	
Postgraduate degree	50 (24%)	16 (28%)	34 (22%)	
Previous diagnosis with iron deficiency	74 (35%)	4 (7.0%)	70 (45%)	**<0.001[3]**
Use of vitamin B12 injections	28 (13%)	9 (16%)	19 (12%)	0.50[3]
Animal motive Scores	6.54 (0.81)	6.35 (0.95)	6.61 (0.75)	0.069[4]
Environment motive scores	6.09 (1.19)	6.00 (1.32)	6.13 (1.14)	0.485[4]
Health motive scores	5.43 (1.70)	5.33 (1.82)	5.47 (1.66)	0.611[4]

[1]mean (SD) or n (%)
[2]Wilcoxon rank sum test
[3]Fisher's exact test; Pearson's Chi-squared test
[4]Independent t-test

3.3.2 Motivations

Animal ethics was found to be the greatest motivator for following a vegan diet, with only 0.5% of participants ranking it not important at all. This was closely followed by the environment with 97.5% of participants ranking it as either a moderately or very important motivator. Health as a motivator had the greatest number of participants who did not consider it to be an important motivator (10.8%), however, over half of the participants still considered it to be a very important motivator (Table 3.2).

Table 3.2: Frequency of the importance of animal ethics, the environment, and health as motivators for following a vegan diet

Motivation type	Not important (%)	Moderately important (%)	Very important (%)
Animal ethics	0.5	16	83.5
Environment	2.4	25.8	71.7
Health	10.8	35.7	53.3

VEMI questionnaire, individuals ranked statements on a scale of 1 – 7 as "not important" (scores 1-2), "moderately important" (scores 3-5), and "very important" (scores 6-7).

Amongst other motivators for following a vegan diet, family was found to be the most important motivator, with 38.7% of participants ranking it as either a moderately or very important motivator (Table 3.3). This was followed by the motivators of friend, and allergy which had similar distribution of participants across importance levels. The least important motivator was classmate.

Table 3.3: Frequency of the importance of other motivators for following a vegan diet

Motivation type	Not Important (%)	Moderately important (%)	Very important (%)
Culture	88.2	7.5	4.3
Allergy	74.6	18.9	6.6
Family	61.3	22.6	16.1
Classmate	90.1	9.0	0.9
Friend	71.7	22.2	6.1
Workmate	86.3	11.8	1.8

Participants also ranked other motivations for following a vegan diet on a scale of 1-7 as "not important" (scores 1-2), "moderately important" (scores 3-5), and "very important" (scores 6-7)

3.3.3 Micronutrient intake

The mean intake of vitamin B12 (supplements excluded) overall and for women did not meet the EAR set of 2.0µg.day. The mean intake for men only just met the EAR. Overall, vitamin B12 intakes ranged from 0.00µg.day to 11.39µg.day.

Mean intake of iron (supplements excluded) of 18.77mg.day (6.02) exceeded the EAR of 6mg.day for all ages of men and the EAR of 8mg.day for women aged 19-50years and 5mg.day for women aged

>51years. The EAR was met by all groups even after lower bioavailability was adjusted for by increasing the EAR by 80% (Table 3.4).

Table 3.4: Average daily intake of energy, iron, and vitamin B12

Characteristic	Overall n = 212[1]	Male n = 58[1]	Female n = 154[1]	*p-value*[2]
Energy (kJ.day)	9,077.39 (2,519.25)	11,304.55 (2,652.36)	8,256.02 (1,902.45)	**<0.001**
Iron intake (mg.day)	18.77 (6.02)	22.36 (6.22)	17.41 (5.36)	**<0.001**
Vitamin B12 intake (μg.day)	1.64 (1.46)	2.05 (1.74)	1.48 (1.31)	**0.004**

[1] **Mean (SD)**
[2] **Wilcoxon rank sum test**

3.3.4 Supplement use

Overall, 63% of participants used vitamin B12 supplements, making it the most frequently used supplement. This was followed by iron, then omega-3 fatty acids supplements. Women had a significantly greater use of iron supplements than men ($p = 0.002$) (Table 3.5).

Table 3.5: Frequency of supplement use

Supplementation type	Overall n = 212[1]	Males n = 57[1]	Females n = 155[1]	*p-value*[2]
Use of vitamin B12 supplements	135 (63%)	36 (63.2%)	99 (63.9%)	0.924
Use of iron supplements	51 (24.1%)	5 (8.8%)	46 (29.7%)	**0.002**
Use of omega-3 fatty acid supplements	39 (18.4%)	9 (15.8%)	30 (19.4%)	0.552

[1] **n (%)**
[2] **Pearsons Chi Square test**

3.3.5 Micronutrient status

Both men (162.33g.L) and women (151.33g.L) had adequate mean haemoglobin (Hb) serum concentrations for their sex. Adequate Hb range for men is between 130-175g.L and >120g.L for non-pregnant women. Mean serum ferritin was within normal range for both men (65.71μg.L) and women (32.44μg.L). The World Health Organization (WHO) serum ferritin cutoff for iron deficiency is 15μg.L for adults aged 20 – 59 years. Men had significantly higher Hb and serum ferritin concentration than women ($p < 0.001$). Overall mean serum vitamin B12 of 316.54pmol.L (146.18) was within normal range of 170 – 600pmol.L, however a large overall range was observed from 72.00pmol.L to 1,015pmol.L. Overall mean omega-3 index was 3.15%. The overall omega-3 index ranged from 1.95%

to 6.64%, with no participants having a cardioprotective index score of >8%. Although it was not significant, women had a higher mean omega-3 index score than men (*p = 0.069*) (Table 3.6).

Table 3.6: Micronutrient status

Characteristic	Overall n = 212[1]	Male n = 57[1]	Female n = 155[1]	*p-value*[2]
Vitamin B12 status (pmol.L)	316.54 (146.18)	299.95 (145.01)	322.86 (146.62)	0.29
Iron status				
Hemoglobin (g.L)	154.31 (16.15)	162.33 (15.92)	151.33 (15.24)	**<0.001**
Serum ferritin (µg.L)	41.62 (34.97)	65.71 (43.39)	32.44 (25.98)	**<0.001**
Omega-3 status				
Omega-3 index (%)	3.15 (0.70)	3.02 (0.65)	3.20 (0.72)	0.069

[1] **Mean (SD)**
[2] **Wilcoxon rank sum test**

3.3.6 Participant characteristics categorised by health motivation

Participants motivated the greatest by health were older (*p* = 0.025) and had obtained greater education levels (*p* = 0.032). They also had greater significantly higher intake of iron after adjusting for energy intake (*p* = 0.032) but had lower intake of vitamin B12 both before (*p* = 0.005) and after (*p* = 0.006) adjustment of energy intake. Participants used omega-3 fatty acid, iron and vitamin B12 supplementation regardless of level of health motivation (Table 3.7). Nutrient intake was adjusted for energy intake as primary analysis showed that energy was strongly positively correlated with iron and vitamin B12 intake. However, it is known that high energy intake does not always result in higher intake of micronutrients (Willett et al., 1997).

Multiple linear regression was used to understand the relationship between the independent variables (animal motivation, environment motivation, health motivation, education, vitamin B12 or iron supplementation, age, and sex) and the variance of iron and vitamin B12 intake after adjustment for energy intake.

Model 1 was statistically significant (*p* = 0.036) and explains 4.2% of the variance in iron per kJ of energy. Health motivation was significantly associated with iron intake (*p* = 0.028). This was followed by iron supplementation, which also showed significance (*p* = 0.031). No other variable in the model achieved significance. Length of time following a vegan diet was highly correlated with age (r = 0.210, *p* = 0.002) (Table 3.8). Therefore, this was removed from the model to avoid multicollinearity. 19 participants were excluded from the model due to missing four-day food diary data. This left 193 participants with full four-day food diary data available to analyze.

Table 3.7: Participant characteristic categorised by health motivation importance

Characteristic	Overall, n = 212[1]	Low, n = 71[1]	Medium, n = 74[1]	High, n = 67[1]	*p-value*[2]
Health motivation	21.73 (6.81)	13.66 (5.59)	24.04 (1.47)	27.72 (0.45)	**<0.001**
Animal motivation	39.24 (4.88)	39.92 (3.84)	39.32 (4.80)	38.42 (5.82)	0.36
Environment motivation	30.49 (5.96)	28.56 (7.25)	31.61 (4.14)	31.30 (5.73)	**0.012**
Age (years)	39.43 (12.41)	36.66 (12.53)	39.74 (11.93)	42.03 (12.37)	**0.025**
Sex					0.63
Male	57 (27%)	21 (30%)	17 (23%)	19 (28%)	
Female	155 (73%)	50 (70%)	57 (77%)	48 (72%)	
Education level					**0.032**
Lower than Bachelor	66 (31%)	25 (35%)	22 (30%)	19 (28%)	
Bachelor's degree	96 (45%)	22 (31%)	40 (54%)	34 (51%)	
Postgraduate degree	50 (24%)	24 (34%)	12 (16%)	14 (21%)	
Serum ferritin (µg.L.day)	41.62 (34.97)	43.30 (43.01)	36.41 (25.68)	45.83 (34.74)	0.33
Missing	9	5	1	3	
Haemoglobin (g.L.day)	154.31 (16.15)	153.53 (15.96)	152.42 (16.87)	157.27 (15.34)	0.25
Missing	2	1	0	1	
Vitamin B12 (pmol.L.day)	316.54 (146.18)	311.20 (149.18)	340.60 (166.57)	294.59 (112.48)	0.39
Missing	9	5	1	3	
Omega-3 index (%)	3.15 (0.70)	3.16 (0.87)	3.11 (0.57)	3.20 (0.63)	0.53
Missing	13	4	3	6	
Iron (mg.day)	18.77 (6.02)	18.54 (6.55)	18.20 (5.89)	19.60 (5.56)	0.28
Missing	19	5	9	5	
Iron (µg.kJ.day)	2.10 (0.52)	2.03 (0.53)	2.07 (0.57)	2.19 (0.45)	**0.032**
Missing	19	5	9	5	
Vitamin B12 (µg.day)	1.64 (1.46)	2.12 (1.95)	1.55 (1.10)	1.21 (0.96)	**0.005**
Missing	19	5	9	5	
Vitamin B12 (ng.kJ.day)	0.19 (0.17)	0.24 (0.23)	0.18 (0.15)	0.14 (0.10)	**0.006**
Missing	19	5	9	5	
Vitamin B12 supplementation	135 (64%)	39 (55%)	51 (69%)	45 (67%)	0.17
Iron supplementation	51 (24%)	18 (25%)	19 (26%)	14 (21%)	0.76
Omega-3 fatty acid supplementation	39 (18%)	17 (24%)	12 (16%)	10 (15%)	0.33

[1] Mean (SD); n (%)
[2] Kruskal-Wallis rank sum test; Pearson's Chi-squared test

Table 3.8: Relationship of iron intake per kJ of energy and independent variables (n = 193)

Model	Unstandardized Beta (*B*)	Coefficients Std. Error *B*	Standardized Coefficients Beta	95% CI Beta (Lower, Upper)	Adjusted R^2	*p-value*
Model 1					0.042	0.036 (ANOVA)
Animal motive	3.360e-5	0.000	0.051	0.000, 0.000		0.491
Environment motive	-5.458e-5	0.000	-0.126	0.000, 0.000		0.103
Health motive	5.337e-5	0.000	0.173	0.000, 0.000		**0.028**
Education	6.524e-5	0.000	0.093	0.000, 0.000		0.203
Iron supplementation	0.000	0.000	-0.160	0.000, 0.000		**0.031**
Age	4.405e-6	0.000	0.105	0.000, 0.000		0.152
Sex	6.396e-5	0.000	0.054	0.000, 0.000		0.464

Model 1 was statistically significant and explained 4.5% of the variance in vitamin B12 intake per kJ of energy intake. Health motivation was significantly associated with vitamin B12 intake ($p = 0.030$) (Table 3.9). No other variable in the model achieved significance.

Table 3.9: Relationship of vitamin B12 intake per kJ of energy and independent variables (n = 193)

Model	Unstandardized Beta (*B*)	Coefficients Std. Error *B*	Standardized Coefficients Beta	95% CI Beta (Lower, Upper)	Adjusted R^2	*p-value*
Model 1					0.045	0.029 (ANOVA)
Animal motive	1.941E-5	0.000	0.088	0.000, 0.000		0.231
Environment motive	1.835E-6	0.000	0.013	0.000, 0.000		0.868
Health motive	-1.762E-5	0.000	-0.172	0.000, 0.000		**0.030**
Education (Collapsed)	-2.480E-5	0.000	-0.106	0.000, 0.000		0.145
Vitamin B12 supplementation	2.504E-5	0.000	0.069	0.000, 0.000		0.334
Age	-1.617E-6	0.000	-.116	0.000, 0.000		0.110
Sex	-1.734E-6	0.000	-0.004	0.000, 0.000		0.951

3.4 Discussion

To our knowledge this is the first study to investigate the association between strength of health motivation, dietary intake and nutrient status of NZ vegans.

3.4.1 The importance of animal ethics, the environment and health for following the vegan diet

Overall, we found that animal ethics was the strongest motivator for following a vegan diet, with almost all (99.5%) of our participants indicating that it was either very important or moderately important. These results show our participants consider animal ethics to be a greater motivator than other groups of vegans around the world (Dyett et al., 2013; Janssen et al., 2016; Marciniak et al., 2021; North et al., 2021).

The validated vegetarian eating motives inventory (VEMI) questionnaire also indicated a large proportion of participants found the environment to be a very important (71.7%) or moderately important (25.8%) motivator. In comparison, studies carried out by Janssen et al. (2016) and North et al. (2021) that also allowed multiple motivating factors to be chosen, had much fewer participants select the environment, 46.8% and 53.64%, respectively. Greater selection of the environment in our study may reflect the increasing awareness of the impact of our food systems and eating behaviours on the environment in recent years.

Although health was found to be the least important motivator compared with animal ethics, and the environment, over half (53.3%) of the participants still considered it to be a very important reason for being vegan, and over a third (35.7%) considered it to be moderately important. Cumulatively, this is also much greater than results found in other groups of vegans around the world (Dyett et al., 2013; Janssen et al., 2016; Marciniak et al., 2021; North et al., 2021). It is possible that those who are more interested in vegan health and their own health would be more inclined to take part in a health related study. It may also be attributed to the exponential rise in research and knowledge surrounding the health benefits of the vegan diet in the last few years as veganism is becoming increasingly popular.

Our results support the proposition that adoption and maintenance of a dietary pattern is often driven by multiple motivations (Beardsworth & Keil, 1991). However, whether multiple motivations were present from the beginning of the participants' vegan journey is unknown. It has been suggested that motives are likely to develop over time (Beardsworth & Keil, 1991). This may be one reason why the majority of the participants were motivated by 2 or more motives as they all had been vegan for at least 2 years, giving the opportunity for motives to evolve.

3.4.2 Overall dietary intake of vitamin B12, iron and the nutritional status of omega-3 fatty acids, vitamin B12, and iron

Vegan diets have been found to be lower in saturated fats and cholesterol, and higher in antioxidants and fibre due to a greater consumption of fruit, vegetables, legumes, grains, nuts and seeds. All of which are essential for disease prevention, including type 2 diabetes mellitus, cancer, and cardiovascular disease, hypertension and hyperlipidemia. For that reason, the position of Academy of Nutrition and Dietetics is "that appropriately planned vegetarian, including vegan diets are healthful, nutritionally adequate, and are appropriate for all stages of the life cycle" (Academy of Nutrition and Dietetics, 2003). Despite this, there remains concern of the potential inadequacy of particular micronutrients such as iron, vitamin B12, omega-3 fatty acids, iodine, zinc, and calcium as planning requires knowledge, effort, and conscious selection of food and appropriate supplements (Bakaloudi et al., 2021; Davey et al., 2003; Key et al., 2006).

Analysis of four-day food diaries identified that the vegans in this study are exceeding the estimated average requirement (EAR) for iron intake for both men and women, even after increasing the EAR by 80%, which is suggested for those following a vegetarian or vegan diet (Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017). Adequate intake of iron was reflected in markers of iron status, ferritin and haemoglobin, with the mean ferritin and haemoglobin concentrations both within normal ranges for men and women. These results are in line with iron intakes and status of vegans in several other studies (Gallego-Narbón et al., 2019; Storz et al., 2023; Waldmann et al., 2003). With numerous plant sources of iron and a diet rich in vitamin C, maintaining adequate iron intake and status is achievable in a vegan diet despite lower bioavailability of non-haem iron. With only 24.1% of participants overall using iron supplementation, it is unlikely to be the reason why mean ferritin and haemoglobin concentrations were well above cut-offs for diagnosing iron deficiency both when stratified by sex, and when stratified by levels of health motivation.

Neither women nor overall mean intake of vitamin B12 met the EAR. However inadequate intake was not reflected in the vitamin B12 status of the participants, with blood results found to be within normal range for both men and women. There are a few possible interpretations of these results. It could reveal the necessity of supplementation to achieve adequate status, with minimal sources of plant foods rich in vitamin B12 and our four-day food diaries not taking into account nutrients provided by supplements. Vitamin B12 was the most used supplement with 63% of participants consuming a supplement at least once per week. Studies have shown that when vegans have high or regular vitamin B12 supplementation use despite low intake through food, vitamin B12 status is adequate and comparable to omnivores (Gallego-Narbón et al., 2019; Selinger et al., 2019; Storz et al., 2023).

Another theory is that our participants may not have had inadequate intake for long enough to become deficient, especially with a 39.6% of participants being vegan for between 2 and 4 years. With 50 - 80% of vitamin B12 that is secreted in the bile being re-absorbed in the digestive system each day, it can take a long time for deficiency to occur even in the absence of intake (Allen et al., 2018; Žane Temova Rakuša, 2022). Finally, vitamin B12 used to fortify food remains un-bound to food molecules and subsequently has greater bioavailability (~60%) (Allen et al., 2018). As the EAR and RDI are based on the assumption of 50% absorption form B12 in food, it could be that less vitamin B12 is required to meet daily needs if the vitamin B12 source is in the free-form (Australian Government Department of Health and Ageing and New Zealand Ministry of Health, 2017). It is likely that all three theories, play an important role in the maintenance of vitamin B12 status.

The total populations omega-3 index was below 4.0% indicating that our participants have a low cardio-protective diet and a high-risk factor for coronary heart disease (Harris, 2007, 2008). Despite the vegan diet having a wide variety of alpha-linolenic acid (ALA) containing plant foods, this was not surprising given that the conversion of ALA to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) is very limited (0.01-10%) and that the omega-3 index is a measure of the total percentage of EPA plus DHA within red blood cells (Goyens et al., 2005; Harris, 2008; Swanson et al., 2012). Low omega-3 indices observed amongst our participants contradicts the wider body of evidence suggesting that vegan dietary patterns are supportive of cardiovascular health (Craig, 2009; Key et al., 2006). It could be that heart healthy food components such as high ALA, fibre, antioxidants, polyphenols and sterols, and low saturated fat and sodium cumulatively benefit cardiovascular health without the presence of adequate EPA and DHA. It is however unknown to what extent adequate EPA and DHA intake is more important than the forementioned other factors influencing heart health. Omega-3 fatty acids also play important roles in influencing gene expression, reducing inflammatory markers, supporting brain health, and reducing the risk of developing Alzheimer's disease, such that inadequate intake has greater consequences than just cardiovascular health (Cederholm et al., 2013; Tortosa-Caparrós et al., 2017).

3.4.3 The role of health motivation on dietary intake of vitamin B12, iron and the nutritional status of omega-3 fatty acids, vitamin B12, and iron

When participant characteristics were stratified by levels of health motivation, those who were highly motivated by health were found to be significantly older and more educated. This group also had significantly greater iron intake when adjusted for energy intake but significantly lower vitamin B12 intake both before and after adjustment for energy intake. Those who were least motivated by health exceeded the EAR for vitamin B12 intake, however those who were moderately and highly motivated by health did not. Multiple linear regression analysis also confirmed the motivation of health to have the greatest association with iron and vitamin B12 intake after adjustment for energy intake. Strength of health motivation had was not associated with omega-3 index.

As we did not measure participants' nutrition knowledge it can only be speculated that because individuals who were highly motivated by health had higher education levels they are more aware of the risks associated with a vegan diet and are therefore more selective in their food choices. It is also possible that individuals highly motivated by heath believe whole foods are a better source of essential nutrients than supplements or fortified processed foods. On the other hand, those who are less motivated by health may not be as conscious of their nutrient consumption or the consequences of a poorly designed vegan diet. Therefore, they may choose more convenience foods and a reduced variety of foods.

It has been shown that higher avoidance of animal products is associated with significantly higher consumption of ultra-processed foods (UPF), with as much as 39.5% of energy intake coming from UPF in vegans. This is driven by higher intakes of plant-based meat and dairy analogues (PBMDA) (Gehring et al., 2021). The main sources of vitamin B12 in our participants' diets were PBMDA, and energy drinks. Although we did not determine whether those less motivated by health were consuming more PBMDA or energy drinks, because there are limited sources of food rich in vitamin B12 it is likely to be the case. Therefore, individuals less motivated by health may have been unknowingly consuming more vitamin B12 without planning to. Difference in dietary patterns between older, more highly health-motivated participants and younger, less health-motivated participants may also be a cause for these results, as younger age and lower education has been associated with significantly higher UPF consumption (Gehring et al., 2021; Julia et al., 2018). Iron has always been discussed as a nutrient at higher risk of inadequate intake and deficiency for those following a vegan diet, and for many years a vegetarian diet before veganism became popular (Haider et al., 2018). Although mean iron intake after adjustment for energy intake was found to be significantly greater in those highly motivated compared to those less motivated by health, the mean iron intake still met the EAR across all three levels of motivation. The largest sources of iron in our study were legumes, pseudo meats, and tofu. Even if individuals are not eating a wide range of plant foods, adequate intake may still be obtained through iron fortified pseudo meats and PBMDA, therefore unintentionally meeting their requirements. Those that are highly motivated by health may be more conscious of iron sources and may have planned their diet more appropriately, leading to significantly greater intake after adjusting for energy intake.

3.4.4 The role of health motivation on use of vitamin B12, iron and omega-3 supplementation

One might assume that being more motivated by health would mean greater use of supplementation, however, a non-significant distribution of supplement use was found between low, medium and high health motivation levels for iron, vitamin B12 and omega-3 supplements. A study conducted by Radnitz et.al (2015) showed that individuals who were primarily motivated by health consumed fewer vitamin supplements, specifically multivitamins, vitamin D and vitamin B12 however this was related to those primarily motivated by ethical reasons.

3.4.5 Limitations

Our research did not come without limitations. The aim of the VEMI questionnaire is to capture motivation levels across animal ethics, the environment, and health. As a result of this we were unable to determine a primary motive for each individual and subsequently could not compare motivation types to one another. Requiring participants to collect a four-day food diary of their food intake increases participant burden, can lead to underreporting, as well as changing of usual dietary habits to appear healthful or for ease. It was also not possible to add supplements into the food diaries and subsequently could not determine whether individuals were meeting EAR, especially for vitamin B12 through the use of supplements. The FoodWorks database was unable to accurately assess the participants' intake of omega-3 fatty acids and therefore we could not evaluate intake and status together. Length of time consuming adequate or inadequate intakes of micronutrients is a key element that impacts the nutrient stores within our bodies and subsequent blood results. However, we did not adjust for length of time an individual had been following a vegan diet. Supplementation use only included oral micronutrient supplements. However, vitamin B12 injections and iron infusions are also forms of supplementation. Therefore, in hindsight this should have been included to more accurately understand the contribution of supplementation to micronutrient status.

3.4.6 Conclusion

In conclusion, our study revealed most New Zealand vegans are motivated to varying degrees by animal ethics, the environment and health, with very few motivated by only one reason. This supports the idea that dietary choice is frequently driven by multiple motives. This research highlights the advantages and disadvantages of a vegan diet such as the ability to meet iron requirements and sustain appropriate iron status, whilst falling short of vitamin B12 requirements purely from diet alone but also maintaining suitable vitamin B12 status, thus highlighting the need for vitamin B12 supplementation to prevent deficiency. It also emphasizes the inadequacy of EPA and DHA stores despite having plentiful and rich sources of ALA, resulting in a low overall cardioprotective diet categorised by the omega-3 index. This study also provided insight into the role of health motivation on nutrient intake, revealing that an individual's strength of health motivation guides food choice and subsequent intake of important nutrients.

Chapter 4: Conclusion

4.1 Achievements of Aims and Objectives

The overall aim of the research was to determine the relationship between the motivation of health for being vegan and the intake of key nutrients and nutritional status in individuals following a vegan diet. We first hypothesised that animal ethics would be the largest motivation for following a vegan diet, followed by the environment, and finally health. Previous literature from around the world has found animal ethics to be the greatest motivator for following a vegan diet (Janssen et al., 2016; North et al., 2021; Ploll & Stern, 2020; Radnitz et al., 2020). Considering the core message of veganism – to as much as possible avoid the exploitation and harm to animals – it is no surprise that people following a vegan diet choose to do so to prevent animal suffering (The Vegan Society, 2023). Health is commonly considered to be a motivator amongst all dietary choices, thus meaning it is not exclusive to veganism (Haverstock & Forgays, 2012; Trethewey & Jackson, 2019). We found this hypothesis to be true as animal ethics came out as the greatest motivator (99.5% of individuals), which was followed unexpectedly closely by the environment (97.5% of individuals), and health (89.0% of individuals).

Secondly, we hypothesised that participants who were highly motivated by health would have higher intake of iron and vitamin B12 and better nutrient status of iron, vitamin B12 and omega-3 fatty acids than those with low health motivation. The theory of planned behaviour recognises that behavioural intention which is the motivational factors that influence behaviour is the first determinant of whether a behaviour is performed (Ajzen, 1991). Health motivation in the general population has been shown to be correlated with health behaviours such as the use of nutrition information panels, and the likelihood of consuming at least 5 servings of fruit and vegetables per day (Craveiro et al., 2021; Moorman & Matulich, 1993; Petrovici & Ritson, 2006). The literature in this area is however, limited and inconclusive. We found significantly higher intake of iron and significantly lower intake of vitamin B12 after adjustment for energy intake in participants highly motivated by health. There was no association between health motivation level and iron, vitamin B12, and omega-3 status.

Finally, we hypothesised that individuals with higher health motivation would use supplementation more as a means of ensuring adequate intake. This hypothesis is also based on the idea that greater health motivation means more healthful behaviours. However, we found no significant differences in the use of iron, vitamin B12, or omega-3 fatty acid supplements between those who have high health motivation versus those who have low health motivation.

4.2 Research impact

Most participants were European and highly educated, therefore likely to be of high socio-economic status. As little research has been collected on vegans in NZ, these demographics lay the foundation for understanding the characteristics of this population. In comparison to other studies, our participant characteristics are consistent with vegans around the world (Dyett et al., 2013; Janssen et al., 2016; Radnitz et al., 2020).

This is the first study in NZ to describe the importance placed on animal ethics, the environment, and health motivations for following the vegan diet as well as investigate the role of health motivation on intake of key nutrients and nutrient status. This study revealed NZ vegans overall are achieving adequate iron intake and status, thus demonstrating the ability of a vegan diet to provide suitable iron to meet requirements without reliance on supplementation. NZ vegans are not meeting vitamin B12 requirements from diet alone, yet currently have adequate vitamin B12 status. This supports the proposal that vegans need to include a daily vitamin B12 supplement and be actively consuming vitamin B12 fortified foods to maintain stores. We also found omega-3 status is low, revealing low cardioprotective blood stores of EPA and DHA despite there being a large variety of alpha linolenic acid rich plant foods. This is of concern as the impacts of low omega-3 index long-term are unknown despite the vegan diet having other dietary characteristics beneficial for cardiovascular health. It was also discovered that vegans highly motivated by health have significantly greater consumption of iron and significantly less consumption of vitamin B12 after adjustment for energy intake compared to vegans with low health motivation. Whether this is due to knowledge, beliefs, age, or convenience it is unknown.

4.3 Strengths

A strength of the study design was the use of a four-day food diary for participants to record their intake. We asked participants to record three week-days plus one weekend day to provide us with a better representation of habitual intake. Although there are multiple methods used to collect food intake, food diaries remain the most appropriate method of obtaining accurate food and nutrient intake over multiple days (van Staveren et al., 2012).

Another strength was the use of FoodWorks, a reliable database and nutrient analysis software that allowed us access to the nutritional information of thousands of New Zealand and Australian products as well as allowed us to input homemade recipes and create new vegan products. The use of

FoodWorks has meant the participants food diaries have been translated into macro and micronutrient intakes that are as accurate as possible for our population.

The use of the validated Vegetarian Eating Motives Inventory (VEMI), meant we were able to determine whether individuals were motivated by multiple motives as well as the strength of each motivation for following a vegan diet. Previous studies have identified that only asking for an individual's primary motivation is a limitation of their research. This is because it is known that motivations for following dietary patterns are complex, with individuals' dietary choice depending simultaneously on several motivators.

Another strength was that intake and status were measured for both iron and vitamin B12. This allowed us to paint a more nuanced and larger picture as to how nutrient intake impacts status.

4.4 Limitations

Our research did not come without limitations. The aim of the VEMI questionnaire is to capture motivation levels across animal ethics, the environment, and health. As a result of this we were unable to determine a primary motive for each individual and subsequently could not stratify results by motivation type. The questionnaire also only captured motivations at the present moment in time and did not provide insight as to what an individual's initial motivation was or how motivations may have evolved overtime. The structure of the VEMI questionnaire also showed most of the participants to be motivated by all three motives, and in volumes that were much greater than observed in other studies (Dyett et al., 2013; Janssen et al., 2016; Marciniak et al., 2021; North et al., 2021).

The four-day food diary is only a snapshot of an individual's eating patterns, of which most individuals are estimating the quantity of food they are consuming. Estimating intakes has been shown to differ up to 20% from actual intake (LicSc, 1992). This technique of collecting dietary data increases participant burden and can lead to underreporting, as well as changing of usual dietary habits to appear healthful or for ease. We were also unable to add supplements into the food diaries and subsequently could not determine whether individuals were meeting EAR, especially for vitamin B12 through the use of supplements. Including supplements in the food diaries would have allowed us to determine the extent to which individuals relied on supplements for meeting EAR's and RDI's. The databased used was unable to accurately assess the participants intakes of omega-3 fatty acids and therefore we could not evaluate intake and status together.

Length of time consuming adequate or inadequate intakes of micronutrients is a key element that impacts the nutrient stores within our bodies and subsequent blood results. However, we did not adjust for length of time an individual had been following a vegan diet. We removed length of time being vegan from the linear regression model as it was highly positively correlated with age and we wanted to prevent multicollinearity. Adjusting for length of time may have provided a more in-depth picture of the role a vegan diet plays on the nutrient status of an individual.

Supplementation use only included oral micronutrient supplements. However, vitamin B12 injections and iron infusions are also forms of supplementation. Therefore, in hindsight this should have been included to more accurately understand the contribution of supplementation to micronutrient status.

4.5 Final recommendations and future directions for research

Literature on the relationship between motivation type and health outcomes is limited, especially in the vegan population. Further research investigating this is necessary to provide a broader and deeper understanding of how one's motivations influence dietary intake. Understanding how motivation impacts nutrition is specifically important in veganism where removal of all animal products requires a high level of motivation already.

- More research is needed to untangle the food and nutrition behaviours and characteristics of vegan individuals motivated by varying degrees of health. Do values and beliefs, age, convenience, or nutrition knowledge affect food behaviours and the therefore nutritional outcomes? Are these factors more important than health motivation itself?
- Very limited research has investigated the nutrition knowledge, and sources of information of vegans. With the possibility for poorly planned vegan diets to results in severe deficiencies, understanding what nutrition knowledge vegans have to guide their food choices is necessary. As well as what the best way to disseminate this information is.
- Longitudinal studies investigating the impact of low omega-3 index on the health of vegans is needed. This is because low omega-3 fatty acid intake has known negative implications for cognitive development, cardiovascular health as well as cancer risk. The vegan diet however, has many other health benefits, so whether a low omega-3 index for vegans is meaningful for health long-term is unknown.
- As this study only looked at the role of health motivation on intake of iron and vitamin B12, and the status of iron, vitamin B12, and omega-3 index, it would be beneficial to explore other nutrients of concern such as vitamin A, calcium, zinc, iodine, and even protein.

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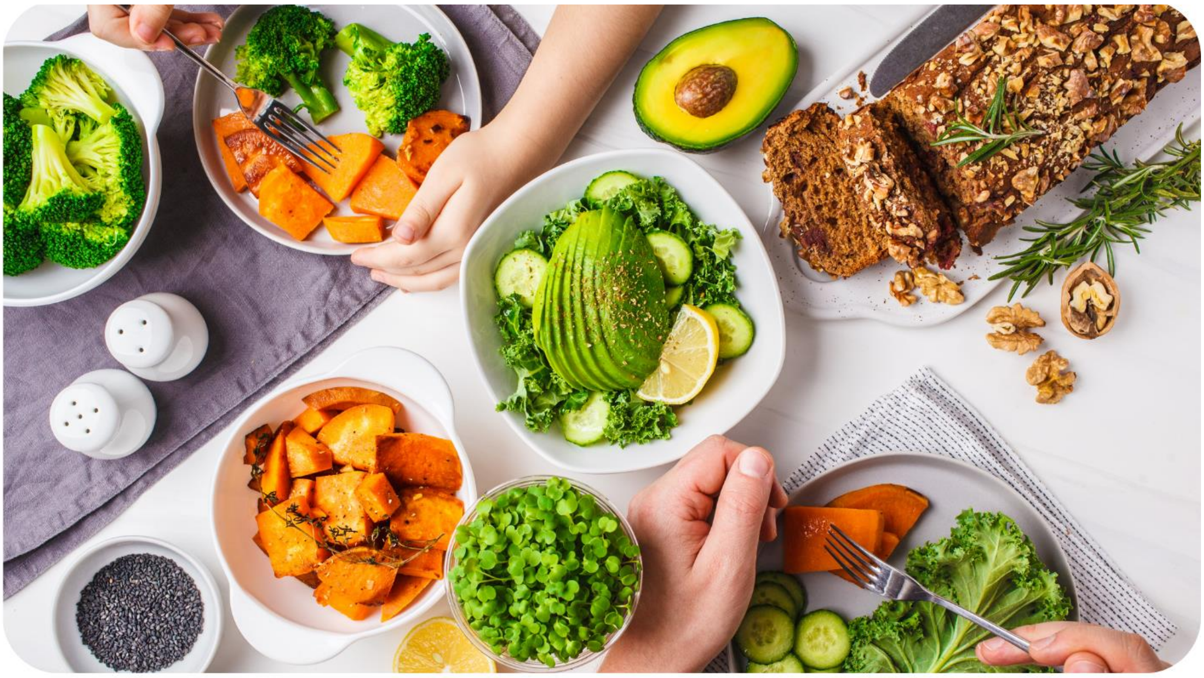
Appendices

Appendix 1: Study recruitment flyer



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MASSEY UNIVERSITY
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UNIVERSITY OF NEW ZEALAND

Appendix 2: Participant information sheet

Participant Information Sheet

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

Health Implications of a Vegan Diet

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. You will be required to bring your diet diary to 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 bone scan 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 (bone density and 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

Appendix 3: Health and Demographic information questionnaire

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. I 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

Appendix 4: Dietary Practices and Supplement use questionnaire

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA
UNIVERSITY OF NEW ZEALAND

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***					

Appendix 5: Four-day food diary instructions and template

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)**
Example7: 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
