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Plant-based diets and health outcomes in Australia and New Zealand

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Abstract

There is mounting interest in the dual health and environmental benefits of plant-based diets. Such diets prioritise whole foods of plant origin and moderate (though occasionally exclude) animal-sourced foods. However, the evidence base on plant-based diets and health outcomes in Australasia is limited and diverse, making it unsuitable for systematic review. This review aimed to assess the current state of play, identify research gaps and suggest good practice recommendations. The consulted evidence base included key studies on plant-based diets and cardiometabolic health or mortality outcomes in Australian and New Zealand adults. Most studies were observational, conducted in Australia, published within the last decade, and relied on a single dietary assessment about 10–30 years ago. Plant-based diets were often examined using categories of vegetarianism, intake of plant or animal protein, or dietary indices. Health outcomes included mortality, type 2 diabetes and insulin resistance, obesity, CVD and metabolic syndrome. While Australia has an emerging and generally favourable evidence base on plant-based diets and health outcomes, New Zealand's evidence base is still nascent. The lack of similar studies hinders the ability to judge the overall certainty of evidence, which could otherwise inform public health policies and strategies without relying on international studies with unconfirmed applicability. The proportional role of plant- and animal-sourced foods in healthy, sustainable diets in Australasia is an underexplored research area with potentially far-reaching implications, especially concerning nutrient adequacy and the combined health and environmental impacts.

Nutrition professionals in Australia and New Zealand generally agree on the basic elements of a healthy diet[1,2]. More specifically, day-to-day food choices that meet energy and nutrient requirements, foster health and well-being and reduce the risk of diet-related chronic diseases. Influential documents include the 2013 Australian Dietary Guidelines[1] and 2015 Eating and Activity Guidelines for New Zealand Adults (updated in 2020)[2]. These guidelines similarly promote a diet centred on fruit, vegetables, whole grains, dairy (or alternatives) and nutrient-dense sources of protein (or 'protein foods', comprising legumes, nuts, seeds, seafood, eggs, poultry and lean red meats). This template of eating aligns well with many international dietary guidelines[3]. Of all the major food groups, 'protein foods' are the most varied in terms of composition and guidance, particularly regarding foods of plant and animal origin. While dietary guidelines have consistently emphasised the importance of plant foods, such as fruit and vegetables[3], newer iterations are starting to expressly encourage a mainly 'plant-based diet' for health and environmental reasons. This includes a preference for plant-based sources of protein, like legumes, combined with limited consumption of red meat. A recent example is the 2023 Nordic Nutrition Recommendations[4].

A plant-based diet prioritises the consumption of fruit, vegetables, cereals, legumes, nuts and seeds while moderating – without necessarily excluding – animal-sourced foods (i.e. seafood, eggs, poultry and dairy, with red meat often singled out for reduction or exclusion). There may also be an emphasis on unprocessed or minimally processed foods ('whole foods'), and the dual health and environmental benefits. This definition (used hereafter) is consistent with the principles of a healthy, sustainable diet[5] and conceptually compatible with the main categories of vegetarianism. These broadly include vegan (no animal-sourced foods), pescatarian (no meat), vegetarian (no meat or seafood) and semi-vegetarian (infrequent consumption of meat, and sometimes seafood, typically ≤ 2 times per week). The term 'plant-based diet', however, is used inconsistently in the literature[6]. It can refer to one or more categories of vegetarianism, a continuum-based measure of adherence like the plant-based diet index[7], a combination of these, or the more abstract notion of a diet centred on foods of plant origin. Given that vegetarianism is proscriptive, where categories are based on the extent of animal food avoidance, the composition and health profile of these diets can vary substantially. There are also geographic and socio-cultural influences to consider[8].

In Australia, there is a lack of current and reliable information on the prevalence of vegetarianism. According to the 1995 National Nutrition Survey, 2·6 % of males and 4·9 % of females (aged ≥ 19 years) described their diet as vegetarian[9]. In 2018, market research estimated that 12·1 % of Australians agreed with the statement: 'The food I eat is all, or almost all, vegetarian'[10]. Conversely, in the New Zealand Health Survey, the prevalence of vegetarianism was established in males and females (aged ≥ 15 years) using strict criteria and data from two collection waves: 2018–2019 and 2019–2020[11]. Overall, 3·0 % of males and 5·3 % of females were classified as either vegan, vegetarian, or pescatarian. A further 2·1 % of males and 3·7 % of females selectively excluded red meat from their diet. Taken together, the prevalence of vegetarianism in Australia and New Zealand appears low, with most opting for a conventional omnivorous diet.

Plant-based diets and alternatives to animal-sourced foods have received significant attention for their emerging role in healthy, sustainable diets. Based on data from the food retail sector, sales of 'dairy and meat substitutes' in Australia increased by 30 % between 2018–2019 and 2022–2023[12]. Typical products include soya 'milk', coconut yoghurt, tofu and meat analogues derived from vegetable or fungi protein. The availability and variety of such products has also increased in recent years, but their healthfulness in terms of nutrient profile, level of food processing and equivalence to animal-sourced foods can vary widely[13–15]. As part of their review of the 2013 Australian Dietary Guidelines, the Dietary Guidelines Expert Committee assigned a 'very high' level of priority to only three health-related topics: dietary patterns at the population level, animal *v.* plant sources of protein, and ultra-processed food intake[16]. These topics will thus be 'comprehensively addressed' by systematic reviews. Stakeholders also flagged food processing, plant-based diets and sustainability as new areas of interest. In the last five years, there has been an influx of research articles on plant-based diets and a range of health outcomes in populations of Australians and New Zealanders, but the overall body of evidence base remains limited and methodologically diverse, making it unsuitable for systematic review.

The aim of this review was to consider the current evidence base on plant-based diets and health outcomes in Australasia. Here, we focus on cardiometabolic health and mortality outcomes in adults from Australia and New Zealand, two countries that share demographic, social and cultural similarities. We also highlight research gaps and suggest good practice recommendations to support future research endeavours.

Plant-based diets and health outcomes

Thirteen original research articles, mostly observational studies conducted in Australia, have been published on the relationship between plant-based diets and cardiometabolic health or mortality outcomes in Australian and New Zealand adults[17–29]. These key studies form the core evidence base of this review.

Mortality

In Australia and New Zealand, the life expectancy at birth is 80–85 years, with females living about 4 years longer than males[30,31]. Leading causes of death include coronary heart disease, cerebrovascular disease and cancer (e.g. lung, colorectal, prostate and breast)[32,33]. There is widespread interest in modifiable risk factors that can reduce the risk of dying prematurely – and ideally, time spent living with illness as well. Put another way, practical ways of adding both years to life and life to years. Three studies in Australia have investigated longevity in relation to a traditional Mediterranean diet[17], categories of vegetarianism[18] and food sources of plant and animal protein[19].

In 330 Greek and Anglo-Celtic participants aged ≥ 70 years, Kouris-Blazos *et al.* examined a traditional Mediterranean diet score in 1990–1992 and subsequent all-cause mortality[17]. This cohort formed part of the Food Habits in Later Life Study[34]. Using food frequency questionnaire data and median values as cut points, eight dietary characteristics were scored favourably: higher consumption of cereals, fruit, vegetables and legumes; higher monounsaturated to saturated fat ratio; lower consumption of meat and dairy; and moderate ethanol intake. After adjusting for age, sex and smoking, each one-unit increment in diet score was associated with a mortality rate ratio of 0·83 (95 % CI: 0·67, 1·02) over the next 4–6 years. Thus, better compliance with the core elements of a traditional Mediterranean diet may enhance survival among elderly Australians. However, interpretive caution is warranted due to the small sample size and number of events (38 deaths), short-term follow-up, risk of unmeasured confounding, and the absence of cause-specific mortality data.

Leveraging the 45 and Up Study, a large population-based cohort of Australians, Mihrshahi *et al.* compared categories of vegetarianism to a reference group of omnivores (who consumed meat more than once per week) with respect to all-cause mortality[18]. Investigators used diet screener data from 2006–2008 to categorise participants as vegetarian, pescatarian, or semi-vegetarian (comprising < 2 % of the available pool of over 243 000 participants aged 62 years on average). During a mean follow-up of 6 years, there was no clear association between categories of vegetarianism and all-cause mortality compared to the omnivore group, except perhaps for pescatarians (hazard ratio: 0·79, 95 % CI: 0·59, 1·06). As such, the question of whether Australian vegetarians have a survival advantage over their omnivorous counterparts remains ambiguous. That said, design considerations include the lack of statistical power (e.g. there were only 46 deaths among pescatarians), short-term follow-up, risk of misclassified diet categories, and several unknowns regarding participants' cause of death, diet composition and long-term dietary habits.

Finally, in a community sample of 605 elderly men from the Concord Health and Ageing in Men Project, Das *et al.* evaluated the relationship between food sources of plant and animal protein and risk of mortality[19]. Participants completed an interviewer-administered diet history questionnaire in 2010–2013. Modelled sources of plant protein included cereals, legumes, nuts and seeds, milk alternatives and soya-based products, while sources of animal protein included meat, seafood, eggs, and dairy. Over a median follow-up of 4 years, where 105 men died (17·4 %), each daily serve of animal foods predicted higher all-cause mortality in energy-adjusted models (hazard ratio: 1·12, 95 % CI: 1·00, 1·26). In contrast, plant foods predicted lower all-cause mortality (hazard ratio: 0·75, 95 % CI: 0·61, 0·92), along with fewer deaths from cancer and CVD. Therefore, obtaining a higher proportion of protein from plant sources (in place of a mix of other foods in the diet) may enhance survival in elderly Australian men. Nonetheless, methodological drawbacks include the small sample size, short-term follow-up, risk of dietary measurement error, and loss to follow-up (since this analysis involved about 35 % of total enrolments, raising concerns about survivorship bias). Also, a specified food substitution model, where a suitable replacement food is also proposed, would have resulted in a more straightforward interpretation of results[35].

Type 2 diabetes and insulin resistance

Type 2 diabetes is a chronic condition characterised by elevated and poorly controlled levels of circulating glucose[36]. The core defects of which include progressive beta-cell dysfunction and insulin resistance, particularly in hepatic and muscle tissue[37]. A tipping point is eventually reached where the pancreatic supply of insulin is unable to meet physiological demands, resulting in overt hyperglycaemia. Despite numerous genetic and lifestyle risk factors[38], the cause of type 2 diabetes appears relatively simple: chronic overnutrition leading to excess lipid accumulation in the liver and pancreas once an individual exceeds their 'personal fat threshold' (i.e. capacity to effectively sequester surplus energy into subcutaneous fat stores)[39]. Though likely an underestimation, the prevalence of diabetes among those aged ≥ 15 years in Australia and New Zealand is 6·0–6·5 %, with type 2 diabetes accounting for about 90 % of cases[40,41]. Type 2 diabetes places an immense burden on society in the form of death, disability and economic strain[42]. As such, research efforts often focus on modifiable risk factors to inform primary prevention strategies, though the avoidance of adverse risk factors is also of interest (i.e. primordial prevention). Two studies in Australia have investigated the intake of protein from plant and animal sources[20], and categories of vegetarianism[21], in the development of type 2 diabetes. In addition, two studies have investigated the link between insulin resistance and adherence to a plant-based diet[22], including the statistical substitution of red meat with plant-based options[23].

To explore the relationship between protein intake from plant and animal sources and type 2 diabetes, Shang *et al.* utilised the Melbourne Collaborative Cohort Study, a large cohort of Australians with an oversampled population of southern European migrants[20]. Data from 21 523 participants (mostly aged 40–69 years) were analysed. Protein intake (as a per cent of total energy intake) was assessed using food frequency questionnaire data in 1990–1994. Diabetes was determined by participant self-report and capillary blood glucose levels at follow-up (2003–2007), with the 929 new cases assumed to be type 2 diabetes. During a mean follow-up of 12 years, each 5 % increment in energy from animal protein instead of carbohydrate was associated with a higher likelihood of type 2 diabetes regardless of BMI (OR: 1·15, 95 % CI: 1·00, 1·33), whereas plant protein was neutral – though protective when restricted to females (OR: 0·60, 95 % CI: 0·37, 0·99). As such, eating patterns with a lower proportion of protein from animal sources may reduce the risk of developing type 2 diabetes in middle-aged adults. Although, it is important to acknowledge the lack of variation in plant protein intake, risk of dietary measurement error and possible differential loss to follow-up.

Using data from the Australian Longitudinal Study on Women's Health, Baleato *et al.* examined categories of vegetarianism and the prevalence of self-reported impaired glucose tolerance and diabetes within the last three years[21]. This descriptive study involved 9003 participants aged 62–67 years from the 2013 follow-up. Food frequency questionnaire data were used to categorise participants as vegan, vegetarian, or pescatarian (comprising 1·4 % of the total sample). Compared to omnivores who consumed meat more than once per week (and a handful of semi-vegetarians), the combined group of vegans, vegetarians and pescatarians had a lower prevalence of impaired glucose tolerance and diabetes (12·2 % *v.* 4·7 %). In this comparison, meat referred to red meat, poultry and seafood, including processed varieties. Overall, older Australian women who abstain from red meat and poultry may be less prone to developing diabetes than omnivores. However, shortcomings include the cross-sectional design, small sample size and number of events, risk of misclassified diet categories and unmeasured confounding, absence of pre-clinical biomarkers (e.g. glucose or glycated haemoglobin), and the lack of information on diet composition.

Two final studies by Goode *et al.* investigated insulin sensitivity and adherence to a plant-based diet[22], as well as plant-centred food substitutions[23], in the Childhood Determinants of Adult Health study. In this population-based sample of Australians, diet was assessed at three time points in adulthood using food frequency questionnaires: 2004–2006, 2009–2011 and 2017–2019. Insulin sensitivity was estimated from fasting glucose and insulin concentrations in 2004–2006 (aged 26–36 years) and 2017–2019 (aged 39–49 years). The average follow-up duration was 13 years. First, a plant-based diet index score was calculated by assigning positive scores to 'healthful' plant foods (the more the better) and reverse scores to all remaining plant and animal foods (the less the better)[22]. In a longitudinal analysis of 667 participants using data from two time points (2004–2006 and 2017–2019), a higher average score, and a higher-than-average score at any time point, was associated with higher insulin sensitivity. Further, this relationship could not be fully explained by adherence to dietary guidelines and adiposity was identified as a potentially important mediator. Thus, a plant-based diet characterised by comparatively higher intakes of plant foods (such as fruit, vegetables, whole grains, legumes and nuts) may have favourable implications for type 2 diabetes prevention. Second, in a food substitution analysis involving 783 participants, statistical modelling was employed to examine the substitution effect of habitually replacing red meat with plant-based options on insulin sensitivity[23]. Daily food group intake (in standard serves) was averaged across all time points, and insulin sensitivity was estimated in 2017–2019. The hypothetical replacement of red meat with whole grains, legumes and nuts (individually or combined) was predictive of higher insulin sensitivity – irrespective of adherence to dietary guidelines. Like before, central adiposity also appeared to be a strong mediator. In relation to mitigating the risk of type 2 diabetes, these findings support advice to (i) shift to a more plant-based diet[22] and (ii) prioritise plant-based sources of protein at the expense of red meat consumption[23]. Shared limitations of these studies include the modest sample sizes, limited ability to separate whole grains from refined grains, and the use of an indirect measure of insulin sensitivity derived from fasted measurements (which principally describes hepatic rather than whole-body insulin sensitivity). Regarding the food substitution analyses, it is worth emphasising that participants were not actively changing their diet, as they would in an interventional study; however, such analyses can still provide insight into the potential net advantage (or disadvantage) of specific food comparisons when interventional studies are not available or feasible.

Obesity

Obesity has historically been defined as 'an excess of body fat frequently resulting in a significant impairment of health'[43]. The fundamental cause is a chronic positive energy balance, but what leads to this state (and its persistence) is complex, and likely involves a range of genetic, psychosocial, cultural, socio-economic and environmental factors. Whether obesity should be labelled a 'disease' has been debated, but medical and scientific organisations have increasingly supported the notion over time[44].

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Epidemiological studies often define obesity using surrogate measures, such as BMI or waist circumference, which do not differentiate between fat mass and fat-free mass. In both Australia[45] and New Zealand[41], about one-third of adults are classified as 'obese' based on a BMI of ≥ 30 kg/m^2. In 2019, noncommunicable diseases attributable to a high BMI were responsible for 8·7 % and 8·5 % of the respective total disease burden in Australia and New Zealand (when expressed as age-standardised disability-adjusted life years), but this rises to over 60 % for diseases such as type 2 diabetes[46]. While BMI is a useful population measure and clinical screening tool, it should not be conflated with a formal diagnosis of obesity[47]. Two observational studies in Australia have investigated the relationship between obesity and adherence to a plant-based diet[24], including categories of vegetarianism[25].

Using data from the North West Adelaide Health Study, a community-based sample of Australians, Wang *et al.* investigated adherence to a plant-based diet (among other diet indices and patterns) and risk of obesity[24]. Plant-based diet index scores were derived from food frequency questionnaire data collected in 2008–2010 by assigning positive scores to 'healthful' plant foods and reverse scores to all remaining plant and animal foods. At the 2015 follow-up, participants self-reported their height and weight, with obesity defined as a BMI of ≥ 30 kg/m^2. Out of 787 participants with a mean age of 59 years, 7·6 % developed obesity during follow-up. When compared to the bottom fifth of the distribution, participants in the top fifth of plant-based diet index scores had a lower risk of developing obesity over the next 5–7 years (0·31, 95 % CI: 0·12, 0·77). However, favourable associations were also found for the other diet indices and patterns studied, such as a 'prudent' dietary pattern derived from principal component analysis. Overall, a diet centred on healthful plant foods (e.g. fruit, vegetables, whole grains, legumes and nuts) may be one of several viable dietary strategies that can support weight management in middle-aged and older Australian adults. Although, design considerations include the small sample size and number of events, use of self-reported anthropometric measurements at follow-up, risk of dietary measurement error, and selection bias as the analysis sample included only 31·5 % of the initial pool of participants.

In another analysis of data from the Australian Longitudinal Study on Women's Health, Ferguson *et al.* explored categories of vegetarianism and surrogate measures of general and central obesity based on self-reported anthropometric measurements[25]. This descriptive study included 9002 participants aged 62–67 years from the 2013 follow-up. As before, food frequency questionnaire data were used to categorise participants as vegan, vegetarian and pescatarian (comprising 1·4 % of the total sample). Compared to omnivores who consumed red meat, poultry, and seafood more than once per week, vegans, vegetarians and pescatarians had, on average, a 3–4 kg/m^2 lower BMI and a 4–11 cm lower waist circumference. Therefore, the omission of red meat and poultry could result in an eating pattern that facilitates better weight management among older Australian women. Such a conclusion, however, must be tempered by the cross-sectional design, small sample size, risk of unmeasured confounding, and lack of information on diet composition.

CVD

CVD is an umbrella term for disorders of the circulatory system. Examples include coronary heart disease, cerebrovascular disease and peripheral artery disease. The most common of which is coronary heart disease and its clinical manifestations: myocardial infarction and angina. These ischaemic conditions (and others) stem from end-stage atherosclerosis, an insidious and complex process that usually begins early in life[48]. During which, plaques slowly accumulate in the walls of arteries over many decades, narrowing the lumen and restricting blood flow, and often culminates in an atherothrombotic event. The principal causal factor in the development of atherosclerosis is cumulative exposure to elevated levels of circulating apolipoprotein B-containing lipoproteins (mostly in the form of low-density lipoproteins)[49–51]. Contributing risk factors include high blood pressure, smoking, diabetes, insufficient physical activity, adiposity and poor dietary habits. In 2022–2023, 6·4 % of Australians and approximately 9·3 % of New Zealanders (aged ≥ 15 years) had CVD, but this rises to 27·7 % and 39·5 % among those aged ≥ 75 years[41,52]. To date, one Australian study has been published on categories of vegetarianism and CVD risk[26]. For completeness, studies are also available on adherence to a vegetarian lifestyle and markers of inflammation[53], as well as lipid and lipoprotein(a) levels among vegetarians compared to omnivores[54,55].

In the Plant-Based Diet Study, Austin *et al.* compared categories of vegetarianism to a reference group of omnivores with respect to predicted risk of CVD[26]. This involved a community-based sample of 240 Australians recruited into groups of 48 participants according to their eating habits over the last six months: vegan, vegetarian, pescatarian, semi-vegetarian and omnivore. Data collection occurred between 2021 and 2023. The 2012 Australian CVD risk calculator (which is based on the Framingham risk equation) was used to predict the risk of an event within the next 5 years as a per cent probability. Compared to omnivores who consumed meat and seafood at least daily, vegans had a slightly lower 5-year risk of CVD (−1·0 %, 95 % CI: −2·1, 0·2), and perhaps semi-vegetarians as well (−0·7 %, 95 % CI: −1·8, 0·4), but not vegetarians or pescatarians. The 5-year risk of CVD in the overall sample and each diet group was not reported. Given participant characteristics, such as dietary fibre intake, which was about double the national average of 23 g/d[56], this appears to be a uniquely health-conscious cohort of participants. Thus, among a seemingly low-risk sample of middle-aged Australians, mostly composed of highly educated females (mean age, 54 years), a vegan diet was most compatible with a lower predicted risk of CVD compared to an omnivorous diet. Methodological considerations include the cross-sectional design, small sample size (which widened confidence intervals and hindered subgroup analyses), and lack of pre-clinical or clinical endpoints.

Metabolic syndrome

Metabolic syndrome (or insulin resistance syndrome) refers to a collection of cardiometabolic abnormalities unified by insulin resistance, typically including some or all of the following: central obesity, hyperglycaemia, dyslipidaemia and hypertension[57]. In 1999–2000, the estimated prevalence of metabolic syndrome in Australian adults ranged from 22 to 31 % depending on the operational definition and choice of thresholds[58]. A 'harmonised' definition was jointly proposed in 2009, with three or more of the following being sufficient for a classification of metabolic syndrome: elevated waist circumference, triglycerides, blood pressure, or fasting glucose; and reduced HDL cholesterol[59]. However, in the prediction of CVD and type 2 diabetes, some

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question the clinical value of metabolic syndrome as a diagnostic category beyond conventional risk algorithms or individual measures of glucose homeostasis[60]. Thus far, one Australian study has examined protein intake from plant and animal sources and risk of metabolic syndrome[27].

In a subsequent investigation in the Melbourne Collaborative Cohort Study, Shang *et al.* examined protein intake from plant and animal sources and metabolic syndrome[27]. As before, protein intake (as a per cent of total energy intake) was assessed using food frequency questionnaires in 1990–1994. Metabolic syndrome was defined using Adult Treatment Panel III criteria in 2003–2007. Out of 5324 participants free of chronic disease at baseline, 8·6 % developed metabolic syndrome during a mean follow-up of 11 years. Compared to the bottom fourth of the distribution, participants in the top fourth of animal protein intake had a higher likelihood of metabolic syndrome regardless of BMI and waist circumference (OR: 1·67, 95 % CI: 1·13, 2·48), whereas a lower likelihood was found for plant protein intake (OR: 0·60, 95 % CI: 0·37, 0·97). Thus, among middle-aged Australian adults, eating patterns with a higher proportion of protein from plant sources (cereals, legumes and nuts) rather than animal sources (red meat and poultry) may reduce the risk of developing metabolic syndrome. This interpretation, however, must contend with the limited variation in plant protein intake, dietary measurement error and possible differential loss to follow-up.

Interventional studies

Despite the well-known importance of lifestyle behaviours for mitigating chronic disease risk (e.g. regular physical activity, not smoking and prudent dietary habits)[61], overall adherence at the population level is usually poor. For instance, only 4·2 % of Australian adults[62] and 6·7 % of New Zealand adults[41] meet the daily recommendation for both fruit and vegetable intake. Public health awareness and implementation are distinct challenges. A potential roadblock is the lack of effective and scalable strategies to empower individuals to make healthful and sustainable dietary changes. One study has evaluated the effectiveness of a vegan diet for reducing BMI and total cholesterol in a clinical population of New Zealanders[28]. Also, one multi-site study has assessed the feasibility of a community-based lifestyle programme (centred on a plant-based diet) for improving cardiometabolic risk factors in Australia and New Zealand[29].

In a prospectively registered randomised controlled trial[63], Wright *et al.* investigated the effectiveness of an *ad libitum*, low-fat, whole-food vegan diet in participants aged 35–70 years from a general practice in New Zealand (2014–2015)[28]. Participants had overweight or obesity and either type 2 diabetes, ischaemic heart disease, hypertension, or hypercholesterolaemia. The primary outcomes were BMI and total cholesterol. Participants were randomised into usual care (*n* 32) or usual care plus diet intervention (*n* 33). To support adherence, the intervention group attended a 12-week, 24-session educational programme aimed at improving health literacy and cooking skills. Food was not provided to participants, only vitamin B_{12} supplements. Compared to controls at 6 months in intention-to-treat analyses, the diet intervention reduced BMI by 3·9 kg/m^2 (95 % CI: −2·9, −4·9) and total cholesterol by 0·5 mmol/l (95 % CI: −0·1, −1·0). The dropout rate was about 25 % in each group. Overall, in a small, motivated group of New Zealand adults with multiple health conditions, encouraging a vegan diet as part of a community-based lifestyle programme promoted clinically meaningful weight loss compared to usual care alone, alongside a modest decrease in total cholesterol. Nonetheless, this interpretation should consider possible treatment contamination due to the open-label design, regression to the mean, lack of information on diet composition and adherence, and the unclear impact of medication changes on total cholesterol.

To assess the effectiveness of the Complete Health Improvement Program in middle-aged adults, Morton *et al.* conducted a pooled analysis of pre-post intervention data from 4 sites in Australia (*n* 105) and 14 sites in New Zealand (*n* 731)[29]. This 30-day lifestyle programme of 16 group sessions is centred on an *ad libitum*, whole-food, plant-based diet, in addition to promoting health literacy, physical activity, stress management and abstinence from substance use. Participants had a high prevalence of CVD risk factors and paid a participation fee of approximately NZ$250. A detailed overview of the Complete Health Improvement Program is available elsewhere[64]. Of 836 enrolled participants, 94·5 % completed the programme between 2006 and 2012. Compared to baseline, participants had, on average, a more favourable cardiovascular risk profile after completing the programme. Of note, LDL cholesterol went from 3·2 to 2·6 mmol/l (−17·9 %) post-intervention. Thus, in motivated Australian and New Zealand adults, participation in a community-based lifestyle programme – focussed on a plant-based diet – may improve a range of CVD risk factors in a relatively short timeframe, particularly in relation to blood lipids. In addition, males may benefit more from this programme than females[65]. That said, key study limitations include the uncontrolled design, risk of unmeasured confounding, uncertainty regarding the contribution of programme components, absence of information on medication changes, and lack of information on diet composition and adherence. In an analysis of 106 participants who completed the programme in New Zealand, most health-related gains waned or reverted after 3–5 years, particularly LDL cholesterol[66].

Discussion

This review provides a current overview of the evidence base on plant-based diets and health outcomes for adults in Australia and New Zealand. Most of this evidence comes from observational studies published within the last decade. Overall, a favourable evidence base is emerging on the relationship between plant-based diets and cardiometabolic health and mortality outcomes in Australia. However, there is an absence of similar studies in New Zealand, except for two interventional studies. To systematically review and assess the certainty of evidence for specific health outcomes in Australasia, more studies with sufficiently well-defined research questions and similar methodology are needed. Furthermore, to increase confidence in effect measures, well-powered cohort studies with long-term follow-up and repeated measures of diet are necessary when randomised controlled trials are not feasible.

Given the limited and diverse evidence base on plant-based diets in Australasia, findings from international studies can supplement knowledge gaps. However, the issue of generalisability requires due consideration from an implementation standpoint. Simply put, can we apply what was learnt about plant-based diets in other countries to Australia or New Zealand? Potential country-specific factors include cultural preferences, socio-economic conditions, food availability, religious practices, cost-effectiveness,

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public health policies, health literacy and the population's background diet. It is worth emphasising that cohort studies do not need to be representative of the general population to establish a diet-disease relationship. In fact, cohort studies are often unrepresentative by design to maximise data quality and exaggerate the contrast in exposure levels.

Whether historical datasets are suitable for topical research questions concerning plant-based diets should be discussed. Although most of the observational studies mentioned in this review were published in the last decade, the underlying dietary data were collected about 10–30 years ago, with the Plant-Based Diet Study being a modern exception[67]. However, prevailing interest in the proportional role of plant- and animal-sourced foods in healthy, sustainable diets is relatively recent[5]. This has been paralleled by a rapid increase in the availability of meat and dairy substitutes in major supermarkets[13,14]. Further, the dynamic and evolving nature of the plant-based food sector means that even the 2022 release of the Australian food composition database may struggle to accurately represent the food supply[68]. In addition, dietary assessment instruments may have a limited capacity to assess the intake of meat and dairy substitutes, unless food lists and accompanying food composition databases are regularly reviewed and updated.

When studying environmental determinants of health such as diet, it is prudent to leverage and fund existing cohort studies for the sake of time and cost efficiency[69]. For instance, investigators may wish to validate dietary assessment instruments, update food lists and accompanying food composition databases, or collect data at additional time points. Yet, there may also be value in establishing new cohort studies (or alternatively, surveys) when funding allows[70]. These new endeavours could employ novel methods and focus on current food environments and practices, which may have changed over time. One example is the Feeding the Future study, a web-based initiative in the United Kingdom to address research questions relating to contemporary plant-based diets[71].

Almost all the observational studies considered in this review assessed diet at a single time point. The net result is usually (but not always) an underestimation of point estimates and loss of precision. Repeated measures of diet can help capture changes over time and mitigate random within-person error, which can attenuate (or 'flatten') regression slopes, known as regression dilution bias[72]. Another concern that poses a greater analytical challenge, particularly for food frequency questionnaires, is systematic within-person error when the extent and direction of bias varies among participants due to conscious or unconscious misreporting. To correct for systematic error in a meaningful way, it is necessary to derive calibration equations from an internal validation study involving a reference instrument. Dietary variables are often subject to both random and systematic error, along with potential misclassification issues as well. In nutritional epidemiology, regression calibration is the default statistical approach to correct for non-differential measurement error in a continuous exposure[73], but is infrequently performed. Compared to a single measure of diet at baseline, cohort studies that model average exposures over time from repeated measures of diet with error correction can substantially strengthen diet-disease relationships. This was eloquently demonstrated by Gu *et al.* using the relationship between red meat consumption and risk of type 2 diabetes[74].

For practical reasons, this review focussed on cardiometabolic health and mortality outcomes in adults, but other health outcomes have also been studied in Australia, but not New Zealand, in the context of a plant-based diet. Examples include gut microbiota composition during early pregnancy[75], glomerular filtration rate among elderly women[76], and depressive symptoms in young adults[77,78]. A few studies have also examined the cardiometabolic health of adolescent vegetarians[79–81].

Numerous diet quality indices, without a specific focus on plant-based diets, have been studied in regard to health outcomes in Australia and New Zealand, including simple Mediterranean-based diet scores, which tend to place a greater emphasis on foods of plant origin[82]. For instance, the Mediterranean Diet Score has been applied in the Melbourne Collaborative Cohort Study[83–88] and Australian Longitudinal Study on Women's Health[89]. While relevant, a full discussion of the Mediterranean diet and accompanying scoring systems, as reviewed elsewhere[90], is beyond the scope of this review. For interested readers, systematic reviews specific to plant-based diets and health outcomes – unrestricted by geographical region – have been published elsewhere[91,92], including the substitution of animal-based foods with plant-based options[93]. Also, noteworthy cohorts of vegetarians (and other categories of vegetarianism) include the Adventist Health Study-2[94], the Oxford component of the European Prospective Investigation into Cancer and Nutrition[95], and the web-based Feeding the Future study[71].

The concept of a plant-based diet is widely recognised yet eludes a clear-cut, granular definition. In practice, however, a plant-based diet (as defined in this review) may be best viewed as a unifying term and guiding principle rather than a quantifiable 'diet'. This could be conceptualised as a dietary compass, helping individuals to orientate their day-to-day food choices by providing direction and something to strive towards. This flexibility is appealing from a public health perspective as it supports personalisation and accommodates (at least in theory) a range of tried-and-true eating patterns (e.g. vegetarian, Mediterranean, and Nordic)[96]. That said, consistency and clarity are needed when discussing 'plant-based diets' in the literature. This can be achieved by providing high-level definitions, citing pertinent research, acknowledging variations in terminology, and, most importantly, presenting information on participant's diet composition in terms of foods and nutrients. In certain situations, it may be preferable to retain well-known terms with specific meanings, such as vegetarian or vegan.

Aside from potential health and environmental benefits, other motivating reasons for excluding some (or all) animal-sourced foods may relate to animal welfare and rights, ethics and morals, culinary tastes and religious beliefs[97]. There are also several health-related conditions that may necessitate the exclusion of certain animal-sourced foods (e.g. lactose intolerance or food allergies). Then again, common perceived barriers to the adoption of a plant-based diet include a lack of knowledge on plant-based nutrition, unwillingness to change current eating habits, insufficient choice when eating out, enjoyment of meat, influence of family and friends, and concerns about nutritional adequacy[98,99]. While outside the scope of this review, the nutrient intake and status of individuals who moderate (or exclude) animal-sourced foods, or switch to plant-based alternatives, is an important issue

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that warrants further consideration. However, nutrients to be mindful of when making such a transition include vitamin B_{12}, omega-3 fatty acids, calcium, zinc and iodine[100,101].

Conclusion

This review contextualises the evidence base on plant-based diets and health outcomes in Australasia, laying the foundation for future research endeavours. To summarise, Box 1 underscores the current state of our understanding of plant-based diets and cardiometabolic health and mortality outcomes in adults. It also highlights research gaps and potential areas for further study. In addition, Box 2 offers a non-exhaustive list of good practice recommendations to consider moving forward. To avoid repetition, guidance is already available on the choice and reporting of plant-based diet indices[102] and food-based substitution models[103]. First and foremost, however, there is a need for well-defined research questions that appreciate the complexities of nutritional exposures[104]. A failure to do so may create more confusion than clarity when conducting an evidence synthesis. We eagerly await future research on the proportional role of plant- and animal-sourced foods in healthy, sustainable diets in Australasia, including the practicalities of transitioning to a more whole-food, plant-based diet.

Box 1. State of play and research gaps in Australasia

- Despite a generally favourable evidence base, the lack of similar studies on plant-based diets and health outcomes hinders the ability to judge the overall certainty of evidence, which could otherwise inform public health policies and strategies
- While it is often more efficient to leverage and fund existing cohort studies, there may also be value in establishing new cohort studies (or surveys) to address research questions related to contemporary plant-based diets and food environments
- When studying diet-disease relationships, repeated measures of diet and calibration equations can mitigate measurement error and substantially improve risk estimation, but to date, most cohort studies have relied on a single measure of diet with no error correction
- Studies involving different types of vegetarianism do not always provide detailed information on diet composition, except perhaps for prohibited foods, making it difficult to identify the food components responsible for an estimated (or observed) health outcome
- The net health and environmental benefit of specific food-based substitutions is an unexplored area of research that could inform win-win public health advice (e.g. replace food *X* with *Y* to reduce both your diet-related chronic disease risk and carbon footprint)
- When transitioning to a more plant-based diet, or replacing animal-sourced foods with plant-based alternatives, the subsequent impact on the intake and bioavailability of key nutrients is not well-established (e.g. vitamin B_{12}, omega fatty acids, calcium, zinc and iodine)
- Despite the popularity of plant-based diets and alternatives to animal-sourced foods, the shortage of accessible, practical and engaging educational material on plant-based nutrition from authoritative sources may discourage receptive and interested members of the public

Box 2. Good practice recommendations

- When using international studies to fill knowledge gaps, examine the applicability of findings to the Australasian context from an implementation standpoint (e.g. cultural preferences, food availability, cost-effectiveness and background diet)
- To support research and monitoring activities, regularly review and update dietary assessment instruments and food composition databases to account for the evolving food environment (and accompanying eating habits) in Australia and New Zealand
- When investigating plant-based diets, and particularly categories of vegetarianism, provide information on the composition of diets with respect to foods and nutrients, including the duration of adherence, to support between-study comparisons and the interpretation of results
- In observational studies on plant-based diets, part (or all) of an association could be due to demographics (e.g. socio-economic status) or other health-orientated behaviours; thus, it is vital to weigh the potential impact of unmeasured and residual confounding on findings
- Given the potential mediating role of adiposity between plant-based diets and cardiometabolic health outcomes, it can be informative to present model assumptions (as directed acyclic graphs) and/or primary analyses with and without a final adjustment for adiposity
- Weigh the possibility of reverse causation bias when drawing conclusions, because a medical event (e.g. a diagnosis of high blood pressure or cholesterol) may prompt individuals to switch to a plant-based diet if deemed 'healthier' or of therapeutic value
- When examining the health properties of plant-based diets, consider overall diet quality before focussing on whether a food is of plant or animal origin, as there can be a wide spectrum of healthfulness in the formulation of both plant-based and omnivorous diets

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