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Review Article

Vegetarian diets, low-meat diets and health: a review

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Abstract

Objective: To review the epidemiological evidence for vegetarian diets, low-meat dietary patterns and their association with health status in adults.
Design: Published literature review focusing primarily on prospective studies and meta-analyses examining the association between vegetarian diets and health outcomes.
Results: Both vegetarian diets and prudent diets allowing small amounts of red meat are associated with reduced risk of diseases, particularly CHD and type 2 diabetes. There is limited evidence of an association between vegetarian diets and cancer prevention. Evidence linking red meat intake, particularly processed meat, and increased risk of CHD, cancer and type 2 diabetes is convincing and provides indirect support for consumption of a plant-based diet.
Conclusions: The health benefits of vegetarian diets are not unique. Prudent plant-based dietary patterns which also allow small intakes of red meat, fish and dairy products have demonstrated significant improvements in health status as well. At this time an optimal dietary intake for health status is unknown. Plant-based diets contain a host of food and nutrients known to have independent health benefits. While vegetarian diets have not shown any adverse effects on health, restrictive and monotonous vegetarian diets may result in nutrient deficiencies with deleterious effects on health. For this reason, appropriate advice is important to ensure a vegetarian diet is nutritionally adequate especially for vulnerable groups.

Keywords
Vegetarian
Meat
Dietary patterns
Health

Over the past 50 years, with the aim of preventing dietary deficiencies, public health authorities have published age- and gender-specific nutrient intake recommendations[1]. While this represents what is considered an 'adequate' diet, there is a lack of consensus regarding 'optimal' dietary intake to reduce the risk of preventable diseases such as CVD, cancer and type 2 diabetes mellitus (T2DM)[2]. In this regard, prospective and cross-sectional studies investigating vegetarian diets and health status provide valuable results. These studies include the Adventist Health Study[3], the Oxford Vegetarian Study[4], the Health Food Shoppers study[5] and the Heidelberg Study[6]. Overall, vegetarians tend to be slimmer, appear to be in better health, with reduced risk of chronic diseases and greater longevity when compared with omnivores[7]. While no reliable estimates for the proportion of vegetarians within populations exist, results of polls and surveys have reported a population prevalence of between 1% and 10% in the European Union, the USA and Canada[8,9].

It is unclear whether established health benefits for vegetarians are attributable to (i) the absence of meat in the diet, (ii) the increased consumption of particular food component(s), (iii) the pattern of foods eaten within the vegetarian diet or (iv) other healthy lifestyle components often associated with vegetarianism. Additionally, restrictive vegetarian diets can be inadequate in terms of nutrient provision and may even be harmful for longer-term health.

The present review details the evidence linking vegetarian diets, low-meat dietary patterns and chronic disease prevention and discusses potential nutritional inadequacies of restrictive vegetarian diets and implications for optimum health status.

Methods

A wide literature search was conducted for the present narrative review using the Ovid MEDLINE (US National Library of Medicine, Bethesda, MD, USA) database for relevant publications up to and including 31 March 2011. The search terms used to identify relevant studies were: 'vegetarian', 'vegan', 'plant-based diets', 'meat', 'cardiovascular disease',

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'blood pressure', 'cholesterol', 'body weight', 'diabetes', 'cancer' and 'dietary patterns'. The primary search was limited to human studies published in the English language. This wide search yielded over 2500 potential articles. Titles and abstracts were screened, and full-text manuscripts were reviewed only if the title/abstract examined vegetarian diets, components of a vegetarian diet or red meat intake in relation to nutritional and/or health outcomes. Review articles, controlled trials and meta-analyses were included. These searches were supplemented with manual searches of reference lists within manuscripts. Approximately 250 full-text articles were reviewed and the most relevant of these (*n* 80) were included in the present overview of the subject area.

What is a vegetarian diet?

Vegetarian diets are often heterogeneous in composition, involving a wide range of dietary practices and individual dietary restriction(s). In practice, adopting a vegetarian dietary pattern is traditionally interpreted to mean an absence of meat[10]. Variations of vegetarian diet include lacto-vegetarians (includes dairy) and lacto-ovo-vegetarians (includes dairy and eggs). Vegan diets have further restrictions imposed and exclude all foods of animal origin. Additionally, vegetarian diets are characterised by high consumption of fruit, vegetables, legumes, nuts, grains and soya protein-food components, and each of these may independently be associated with positive health outcomes[11].

Vegetarian diets and prevention of chronic disease

CVD

A pooled analysis of five prospective cohort studies, involving approximately 76 000 subjects from the USA, the UK and Germany, over a mean follow-up period of 10·6 years, reported that vegetarians had a 24 % (95 % CI 6 %, 38 %) reduction in mortality from CHD compared with regular meat-eaters[12]. Further characterisation of the vegetarian cohorts within that analysis found that the greatest reductions in CHD mortality (34 %) were observed in individuals eating fish but no meat and in lacto-ovo-vegetarians when compared with regular meat-eaters. Furthermore, occasional meat-eaters demonstrated a 20 % reduction in CHD when compared with regular meat-eaters. In that analysis, no significant differences were observed for stroke mortality or overall mortality between vegetarians and non-vegetarians[12]. Recent independent analyses of mortality rates in British vegetarians (EPIC–Oxford, the Oxford arm of the European Investigation into Cancer and Nutrition (EPIC)) and German vegetarians found non-significant reductions in CHD mortality in vegetarians compared with omnivores[13,14] but no significant differences were observed for overall mortality rates between vegetarians and omnivores in these cohorts[13,14]. One possible explanation may be that overall mortality was low in the cohort populations compared with the general Western population. It is unclear whether omnivores included in these cohorts are truly representative of the general population in terms of dietary intake and other lifestyle behaviours. The cohort populations recruited in prospective studies have comprised Seventh Day Adventists and other health-conscious populations, who tend to be healthier than the general population in a number of ways. In addition to a high prevalence of vegetarianism, these populations also report low consumption of tobacco and alcohol and possibly increased levels of physical activity, which have independent benefits for CVD risk[12,13]. Despite consideration of these potential confounders and significant heterogeneity between prospective studies, the current data provide evidence that a vegetarian diet and/or infrequent meat consumption significantly reduces the risk of CHD death. Much of the cardioprotective effect of vegetarian diets has been attributed to differences in observed BMI, cholesterol levels and blood pressure levels between vegetarians and omnivores[13].

Serum total cholesterol (TC), LDL cholesterol (LDL-C) and TAG are significantly lower in vegetarians than omnivores in several studies[15–17]. One study in New Zealand Seventh Day Adventists observed no difference between lipid profiles of vegetarians and omnivores, although lipid profiles in each group were noted to be lower than in the general population[18]. The lipid-lowering effects of vegetarian diets have been demonstrated in small randomised trials[19,20]. A recent review suggests that vegetarian and lacto-ovo-vegetarian diets are associated with reductions in TC and LDL-C of about 10–15 %, vegan diets of approximately 15–25 % and combination diets (vegetarian with added fibre, soya and nuts) of approximately 20–35 %[21], suggesting that the lipid-lowering effects of vegetarian diets is dependent on the actual portfolio of dietary components consumed. Furthermore, it is estimated that risk of CHD is reduced by approximately 1 % for each 1 % reduction in LDL-C[22]. Therefore, the observed reduction in CHD mortality in vegetarian populations appears to be in accordance with the reported lipid-lowering effects of vegetarian and vegan diets.

The incidence of hypertension appears to be lower in vegetarian populations[10]. In a cohort of 11 004 men and women aged 20–78 years, Appleby *et al.*[23] showed differences in age-adjusted mean values between omnivores and vegans of −4·2 mmHg and −2·6 mmHg in systolic blood pressure and −2·8 mmHg and −1·7 mmHg in diastolic blood pressure, for men and women, respectively ($P < 0·005$). There was no significant difference in blood pressure measurements observed between omnivores and vegetarians. After controlling for various confounding variables, the authors concluded that much of the variation in blood pressure was attributable to differences in BMI, with vegan subjects tending to be leaner than the other dietary groups.

Vegetarians and particularly vegans have lower body weights than the general population with a low incidence of obesity[10,24,25]. BMI is on average 1–2 kg/m^2 less in vegetarians and vegans compared with age- and gender-matched non-vegetarians[26]. In the Adventist Health Study, BMI increased as the frequency of consumption of meat increased in both men and women[27]. Furthermore, the EPIC–Oxford cohort consisting of approximately 22 000 individuals, followed up over a mean 5·3 years, demonstrated an average weight gain of 400 g/year overall. When the cohort was subdivided into omnivores, fish-eaters, vegans and vegetarians, there was significantly lower weight gain in vegans ($P < 0·05$) and fish-eaters ($P < 0·001$) but not in vegetarians when compared with omnivores[28]. A recent small randomised controlled trial demonstrated improved efficacy of a vegan diet in long-term weight loss in postmenopausal women compared with a conventional weight-loss diet after 1 year (−4·9 kg *v.* −1·8 kg; $P = 0·02$) and 2 years (−3·1 kg *v.* −0·8 kg; $P = 0·022$)[29].

Cancer

Scientific evidence investigating the relationship between cancer incidence and vegetarian diet is limited. Results of a pooled analysis of five prospective studies found no significant difference between vegetarians and non-vegetarians in mortality from common causes of cancer including lung, colon, stomach, breast and prostate cancers[12]. Overall, epidemiological data suggest that cancer incidence is lower in vegetarians compared with non-vegetarians, although results are inconsistent[27,30,31] and probably depend on cancer site. The largest prospective study of 34 192 Seventh Day Adventists suggested cancer of the colon (relative risk (RR) = 1·88, 95 % CI 1·24, 2·87; $P = 0·003$) and prostate (RR = 1·54, 95 % CI 1·05, 2·26; $P = 0·03$) were significantly more likely in omnivores than in vegetarians[27] although this was not confirmed in a recent pooled analysis from two UK populations[30]. The Adventist study showed no difference in breast cancer incidence (RR = 1·25, 95 % CI 0·87, 1·80; $P = 0·22$) between vegetarians and non-vegetarians[27]. However, results from the UK Women's Cohort Study suggested that women who did not eat any meat had a significantly lower risk for breast cancer than did women who were regular meat-eaters[32]. In that study a dose–response effect was demonstrated, with each increase of 50 g/d in red meat intake increasing breast cancer risk by 11 % (95 % CI 1·04, 1·18), even after adjustment for lifestyle confounders including menopausal status.

Type 2 diabetes mellitus

Epidemiological studies have supported the hypothesis that vegetarian diets protect against T2DM[33]. The Seventh Day Adventist study reported a significantly reduced prevalence of diabetes in vegetarians compared with non-vegetarians[10]. Increased adherence to a vegetarian diet in the Adventist study demonstrated a reduced risk of developing T2DM in an incremental manner[34]. Clinical dietary studies investigating the impact of vegetarian diets in diabetic patients have shown significant reductions in fasting blood sugar, cholesterol and TAG levels[35–37]. However, the results are confounded by resulting significant weight loss in the intervention groups throughout the diet period, in addition to increased exercise and lifestyle modifications in some cases.

Are there specific dietary components in vegetarian diets protective against disease?

Vegetarian diets are characterised by greater consumption of fruit and vegetables containing a myriad of phytochemicals, dietary fibre and antioxidants which may offer protective metabolic advantages for both cancer and CVD risk. Fruit and/or vegetable intake may reduce cancer risk[38–41]. Consumption of fruit and vegetables has consistently been inversely associated with risk of CVD, and this has been confirmed by meta-analyses[42–44]. It is currently recommended that diets should include 400 g of total fruit and vegetables daily, which equates to 5 portions/d[40,41]. There is also evidence to suggest that high fruit and vegetable intakes may reduce the risk of developing T2DM[45,46].

Vegetarian diets tend to be low in SFA and rich in *n*-6 PUFA, which is shown to have favourable effects on blood lipid fractions[25]. When intake of SFA is replaced by PUFA, the risk of CHD is decreased[47].

Nuts are consumed more frequently in vegetarian diets and are good sources of plant sterols, antioxidant vitamins and minerals, MUFA and dietary fibre. A review of epidemiological data reported a 37 % risk reduction in CHD death in adults consuming nuts more than four times weekly and 8·3 % risk reduction for each weekly serving of nuts[48]. A recent pooled analysis of twenty-five trials, involving 583 men and women with normal to increased untreated cholesterol levels, reported an average 5·1 % reduction in TC and 7·4 % reduction in LDL-C levels with a mean nut intake of 67 g/d[49].

Recent interest has focused on the role of foods and food components such as oats (β-glucans), psyllium, soya protein and plant sterols, which may be consumed in greater quantities in vegetarian diets. A meta-analysis involving forty-one randomised controlled trials found soya protein supplementation was associated with a significant reduction in mean TC, LDL-C and TAG and a significant increase in HDL cholesterol[50]. The National Cholesterol Education Program Adult Treatment Panel III guidelines recommend increasing intake of plant sterols or stanols (2 g/d) to help achieve cholesterol treatment goals[51]. Intake of 1–2 g plant sterols/d has been shown to reduce LDL-C by approximately 10–15 %[52]. Furthermore, soya protein contains phyto-oestrogens, specifically isoflavones, which may have a protective role in breast cancer development, especially in Asian women where soyabeans are a staple food[53–55]. In Western women the main source of phyto-oestrogens are lignans, which may also have a protective role in breast cancer development. Recent meta-analyses reported that high levels of plant lignan intake are significantly associated with reduced breast cancer risk in postmenopausal women[56,57].

Reduced meat intake, dietary patterns and protection against disease

The health benefits of vegetarian diets are not necessarily unique. As outlined previously, modest fish and dairy consumption as well as occasional meat intake have also been associated with reduced risk of CHD when compared with regular meat-eaters. In addition, there are inconsistencies in results, particularly for cancer risk in vegetarian and omnivore cohorts, despite convincing evidence linking red meat consumption and cancer risk (discussed later). It appears that populations with small intakes of total meat can also experience health benefits when compared with the general population. In this regard, the dietary patterns approach in nutritional epidemiology provides further evidence that adherence to prudent diets such as the Mediterranean diet and the DASH (Dietary Approaches to Stop Hypertension) diet is associated with significant improvements in health status. These prudent diets are characterised by increased consumption of plant foods, low SFA intake, high dietary fibre intake and low intakes of refined carbohydrate. However, in contrast to vegetarian diets, these prudent dietary patterns also allow consumption of small amounts of red meat in addition to fish and dairy products.

Adherence to a Mediterranean diet has been associated with longevity in a number of large epidemiological studies[58–60]. A meta-analysis of these studies included more than 1·5 million healthy subjects and 40 000 fatal and non-fatal events[61]. The authors concluded that greater adherence to a Mediterranean diet is significantly associated with a reduced risk of overall mortality, CVD mortality and cancer incidence and mortality.

In the Lyon Diet Heart Study, a secondary prevention randomised controlled trial with free-living subjects recently diagnosed with a CHD event, those in the Mediterranean diet intervention group had a 50–70 % reduction of recurrent CHD including cardiac death[62]. Trichopoulou *et al.*[60] assessed the effects of Mediterranean diet score on survival; there were no strong associations seen for each of the individual dietary components of the Mediterranean diet score, suggesting that it is the overall pattern that is protective. Evidence from the DASH study suggests that the DASH diet has a significant lowering effect on blood pressure, independent of body weight and Na intake, in both hypertensive and normotensive adults[63,64]. A recent prospective study evaluated the association between a DASH-style diet adherence score and CHD risk in women[65]. Diet was assessed seven times during 24 years of follow-up. Women with a high DASH score had a lower risk of CHD: those in the top quintile of the DASH score had an RR of 0·76, compared with those in the bottom quintile ($P < 0{\cdot}001$ for trend).

Is an absence of red meat protective against disease?

Components of vegetarian diets are not always clearly defined across studies. While emphasis is on increased consumption of plant foods, the actual dietary quality in terms of nutrient intake can be variable. The only known constant in a vegetarian diet is the absence of red meat. Therefore, evidence linking red meat and health status can be valuable when considering the overall potential effects of vegetarian diets and health.

Red and processed meat intake has been positively associated with CVD, T2DM and certain cancers in epidemiological studies[66,67]. The NIH (National Institutes of Health)–AARP (formerly known as the American Association of Retired Persons) prospective study from the USA, involving over half a million adults aged 50–71 years over 10 years, found increased risk of total mortality and CVD mortality among those in the highest quintile of red meat and processed meat intake, compared with those in the lowest quintile[66]. However, individuals in the highest quintile of meat intake were also more likely to have higher BMI, increased smoking and sedentary lifestyles. These lifestyle factors are inherently difficult to measure, so the effects of residual confounding may not have been fully accounted for in the overall analysis. A recent large systematic review and meta-analysis involving twenty studies, including Sinha *et al.*[66], found no significant association between red meat intake and incident CHD, but did find that consumption of processed meats was associated with a 42 % higher CHD risk for each 50 g/d increase in intake[67].

The second report published by the World Cancer Research Fund/American Institute for Cancer Research[41] found meat consumption to be the only convincing dietary factor associated with increased risk of colon cancer. Even so, colon cancer incidence rates in vegetarian populations compared with omnivores are not consistent between UK and US prospective studies as mentioned previously[10].

Additionally, a recent systematic review, involving seven prospective cohorts, concluded that processed meat consumption of 50 g/d is associated with a 19 % higher risk of diabetes, while consumption of unprocessed red meat is associated with a non-significant trend towards a higher risk of diabetes[67].

Nutritional adequacy of vegetarian diets

Carefully planned vegetarian and vegan diets can provide adequate nutrients for optimum health[11]. Evidence suggests that infants and children can be successfully reared on vegan and vegetarian diets[68,69]. However, all dietary practices, including non-vegetarian diets, can be deleterious for health if essential nutrients are not consumed according to an individual's needs. Therefore, vegetarian and vegan diets need to ensure a balance of nutrients from a wide variety of foods, especially for vulnerable groups such as pregnant or lactating women and children. Nutrients most likely to be deficient in unbalanced or very restrictive vegetarian diets are Fe, vitamin D, vitamin B_{12} and *n*-3 fatty acids.

Fe

Fe deficiency occurs as a result of inadequate intake and/or poor bioavailability from the diet. An adequate intake of Fe in vegetarians and vegans has been demonstrated but the incidence of Fe-deficiency anaemia is no greater in vegetarians than in omnivores although Fe stores tend to be lower, especially in women[70]. It is recommended that Fe intakes be higher in vegetarians and vegans[11], as plant sources of Fe (non-haem) are less bioavailable. Furthermore, phytate, soya protein and polyphenols/tannin within a plant-based diet can inhibit Fe absorption further. Ascorbic acid, retinol, alcohol and carotenes can enhance the absorption of non-haem Fe[70].

Vitamin B_{12} (cobalamin)

Vitamin B_{12} is required by the body only in small amounts but is almost completely restricted to foods of animal origin. Deficiency of vitamin B_{12} can cause pernicious anaemia and can result in megaloblastic anaemia with central nervous system demyelination if not treated early[71]. The difficulty in diagnosing vitamin B_{12} deficiency prior to symptom development in vegetarians can be due to a high folic acid intake: this can mask the haematological signs of deficiency. Since folate intake is often higher in vegan diets, elevated serum methylmalonic acid, holo-transcobalamin and/or homocysteine may be more sensitive indicators of a vitamin B_{12} deficiency[71]. Several studies have consistently reported lower vitamin B_{12} status and higher homocysteine levels in vegetarians, particularly vegans, when compared with omnivores[72,73]. Purported plant-based sources (tempeh, algae extracts and sea vegetables) have been found to contain more inactive corrinoids than true vitamin B_{12}[71] and thus they are not reliable sources of B_{12}. Risk of vitamin B_{12} deficiency in vegans is increased if the diet is not supplemented with fortified products (fortified yeast extract, fortified soya products and breakfast cereals).

Vitamin D

Dietary sources of vitamin D include oily fish, fortified margarines and breakfast cereals. Vegan and very restrictive vegetarian diets pose risk of deficiency, particularly among those living in northern latitudes where there is less opportunity for sunlight exposure. Lower serum 25-hydroxyvitamin D levels have been reported in vegetarians and vegans compared with omnivores[74]. Emerging evidence suggests a role for optimal vitamin D status in disease prevention including CVD, cancer and T2DM[75–77], therefore maintaining adequate status is important. Dietary sources include fortified soya milks and cheeses and margarines. In some cases a vitamin D supplement may be required[11].

n-3 Fatty Acids

n-3 Fatty acids are thought to be important for immune, cognitive and cardiac function. Vegetarian diets may be lower in *n*-3 fatty acids, in particular the marine fatty acids EPA and DHA, and higher in *n*-6 fatty acids (linoleic acid)[11]. Plant derived α-linolenic acid can be converted to EPA and DHA *in vivo*, but the rate of conversion is low[78]. Consequently, lower serum levels of EPA and DHA have been reported in vegans[79,80] as well as lower erythrocyte phospholipids *n*-3 status in vegans and vegetarians[81]. The health effects of lower marine *n*-3 fatty acid status are not known at this time[80]. Vegan sources of *n*-3 fatty acids include flaxseed and flaxseed oil, canola oil, olive oil and/or vegan DHA supplement[11].

Conclusions

Vegetarian diets are associated with reduced risk of CHD and T2DM in health-conscious individuals. At present, there is limited evidence of a beneficial effect of vegetarianism in reducing risk of cancer and further studies are warranted. A major problem with recommending vegetarian diets for improved health is that a vegetarian diet is inadequately defined in terms of nutrient and food content. The only certain aspect of a vegetarian diet, by definition, is the absence of red meat. Other prudent dietary patterns allowing small amounts of lean red meat appear to offer significant protection against CVD, cancer and overall mortality. Findings from cohort studies to date indicate that increased meat consumption, especially processed meat, is positively and strongly associated with incident CHD, T2DM, perhaps colon cancer and all-cause mortality, independent of other lifestyle factors.

At this time, it is unclear whether the absence of meat and meat products from the vegetarian diet, or whether differences in type and variety of foods replaced when meat is infrequently consumed, explains the observed reduction in mortality from CHD in vegetarian cohorts. Additionally, it is not known whether a particular food, dietary compound or a combination of dietary or lifestyle/behavioural factors in the vegetarian diet provides optimal protection against chronic disease development.

It is recognised that over-reliance on one single food, or food group, will not provide the range of nutrients required for optimum health and well-being. This is the case for all diets – omnivorous, vegetarian or vegan. Regardless of the degree of vegetarianism, exclusion of major food groups from the diet is likely to result in nutrient deficiencies, particularly for vulnerable groups such as infants, menstruating women and pregnant or lactating women.

In conclusion, based on available evidence to date, all dietary practices should aim to meet current nutritional guidelines to reduce risk of chronic disease development[82]. A diet low in SFA, refined sugar, processed meat and salt, and rich in fruit and vegetables and dietary fibre, is recommended. Moderation and variety in individual diets is also important. Vegetarian dietary patterns need to be adequately defined and further intervention trials are required before they can be widely advocated for optimal health status.

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