Health effects of vegan diets[1–3]

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ABSTRACT

Recently, vegetarian diets have experienced an increase in popularity. A vegetarian diet is associated with many health benefits because of its higher content of fiber, folic acid, vitamins C and E, potassium, magnesium, and many phytochemicals and a fat content that is more unsaturated. Compared with other vegetarian diets, vegan diets tend to contain less saturated fat and cholesterol and more dietary fiber. Vegans tend to be thinner, have lower serum cholesterol, and lower blood pressure, reducing their risk of heart disease. However, eliminating all animal products from the diet increases the risk of certain nutritional deficiencies. Micronutrients of special concern for the vegan include vitamins B-12 and D, calcium, and long-chain n–3 (omega-3) fatty acids. Unless vegans regularly consume foods that are fortified with these nutrients, appropriate supplements should be consumed. In some cases, iron and zinc status of vegans may also be of concern because of the limited bioavailability of these minerals. *Am J Clin Nutr* 2009;89(suppl):1627S–33S.

INTRODUCTION

A nationwide poll conducted in April 2006 by Harris Interactive reported that 1.4% of the American population is vegan, in that they eat no meat, fish, dairy, or eggs (1). Vegan diets are growing in popularity today among teenagers and youth, especially females. For many vegans, nutritional choices center around taking better care of the earth's resources and the environment, ethical issues about animal care, the use of antibiotics and growth stimulants for the production of animals, the threat of animal-borne diseases, and the health advantages of a plant-based diet (2–6). In addition, the potential of allergies from dairy products and lactose intolerance have fueled the popularity of soy-based dairy substitutes.

What then is the nutritional and health status of those who follow a vegan diet? Compared with other vegetarians (eg, lactoovovegetarians), are there any advantages or disadvantages to following a vegan diet? Does the elimination of dairy and eggs offer any additional benefits or create potential concerns? The purpose of this brief review is to summarize current knowledge on the health effects of vegan diets, to discuss the nutritional concerns or shortfalls of a vegan diet and to provide some practical dietary recommendations for following a healthy vegan diet. Key et al (7) have provided a pertinent overview of the health effects of vegetarian diets, focusing on their European Prospective Investigation into Cancer and Nutrition–Oxford (EPIC-Oxford) study and other large population studies.

HEALTH EFFECTS OF VEGAN DIETS

Vegan diets are usually higher in dietary fiber, magnesium, folic acid, vitamins C and E, iron, and phytochemicals, and they tend to be lower in calories, saturated fat and cholesterol, long-chain n–3 (omega-3) fatty acids, vitamin D, calcium, zinc, and vitamin B-12 (8). In general, vegetarians typically enjoy a lower risk of cardiovascular disease (CVD), obesity, type 2 diabetes, and some cancers (3). A vegan diet appears to be useful for increasing the intake of protective nutrients and phytochemicals and for minimizing the intake of dietary factors implicated in several chronic diseases (9). In a recent report (10), different plant food groups were rated with respect to their metabolic-epidemiologic evidence for influencing chronic disease reduction. According to the evidence criteria of the World Health Organization and Food and Agriculture Organization (WHO/FAO), cancer risk reduction associated with a high intake of fruit and vegetables was assessed as probable or possible, risk of CVD reduction as convincing, whereas lower risk of osteoporosis was assessed as probable (10). The evidence for a risk-reducing effect of consuming whole grains was assessed as possible for colorectal cancer and probable for type 2 diabetes and CVD. The evidence for a risk-reducing effect of consuming nuts was assessed as probable for CVD (10).

Cardiovascular disease

In summarizing the published research, Fraser (11) noted that, compared with other vegetarians, vegans are thinner, have lower total and LDL cholesterol, and modestly lower blood pressure. This is true not only for whites; work by Toohey et al (12) showed that blood lipids and body mass index (BMI; in kg/m^2) were significantly lower in African American vegans than in lacto-ovovegetarians. Similarly, among Latin Americans, vegetarians had lower plasma lipids than did their omnivore counterparts, with the lowest reported among vegans (13). In that study, plasma total and LDL cholesterol were 32% and 44% lower among vegans than among omnivores. Because obesity is a significant risk factor for CVD, the substantially lower mean BMI observed in

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First published online March 11, 2009; doi: 10.3945/ajcn.2009.26736N.

vegans may be an important protective factor for lowering blood lipids and reducing the risk of heart disease (8).

Vegans, compared with omnivores, consume substantially greater quantities of fruit and vegetables (14–16). A higher consumption of fruit and vegetables, which are rich in fiber, folic acid, antioxidants, and phytochemicals, is associated with lower blood cholesterol concentrations (17), a lower incidence of stroke, and a lower risk of mortality from stroke and ischemic heart disease (18, 19). Vegans also have a higher consumption of whole grains, soy, and nuts (14, 15, 20), all of which provide significant cardioprotective effects (21, 22).

Cancer

Data from the Adventist Health Study showed that nonvegetarians had a substantially increased risk of both colorectal and prostate cancer than did vegetarians (23). A vegetarian diet provides a variety of cancer-protective dietary factors (24). In addition, obesity is a significant factor, increasing the risk of cancer at a number of sites (25). Because the mean BMI of vegans is considerably lower than that of nonvegetarians (8), it may be an important protective factor for lowering cancer risk.

Vegans consume considerably more legumes, total fruit and vegetables, tomatoes, allium vegetables, fiber, and vitamin C than do omnivores (14–16, 20, 23). All those foods and nutrients are protective against cancer (25). Fruit and vegetables are described as protective against cancer of the lung, mouth, esophagus, and stomach and to a lesser degree some other sites, whereas the regular use of legumes provides a measure of protection against stomach and prostate cancer. In addition, fiber, vitamin C, carotenoids, flavonoids, and other phytochemicals in the diet are shown to exhibit protection against various cancers, whereas allium vegetables provide protection against stomach cancer, and garlic against colorectal cancer. Foods rich in lycopene, such as tomatoes, are known to protect against prostate cancer (25).

Fruit and vegetables are known to contain a complex mixture of phytochemicals that possess potent antioxidant and antiproliferative activity and show additive and synergistic effects (24, 26). The phytochemicals interfere with several cellular processes involved in the progression of cancer. These mechanisms include inhibiting cell proliferation, inhibition of DNA adduct formation, inhibiting phase 1 enzymes, inhibiting signal transduction pathways and oncogene expression, inducing cell-cycle arrest and apoptosis, inducing phase 2 enzymes, blocking the activation of nuclear factor-κB, and inhibiting angiogenesis (24).

With this wide array of useful phytochemicals in the vegetarian diet, it is surprising that population studies have not shown more pronounced differences in cancer incidence or mortality rates between vegetarians and nonvegetarians (7, 27). The bioavailability of the phytochemicals, which depends among other things on food preparation methods, may be an important determining factor. However, new evidence suggests that a low vitamin D status, a problem often reported in vegan populations (8, 28), is associated with an increased risk of cancers (29, 30).

The sources of protein avoided or consumed by vegans also have definite health consequences. Red meat and processed meat consumption are consistently associated with an increase risk of colorectal cancer (25). Those in the highest quintile of red meat intake had elevated risks, ranging from 20% to 60%, of esophageal, liver, colorectal, and lung cancers than did those in the lowest quintile of red meat intake (31). In addition, the use of eggs was recently shown to be associated with a higher risk of pancreatic cancer (32). Although vegans avoid consuming red meat and eggs altogether, they consume greater amounts of legumes than do omnivores (14, 16, 20). This protein source was seen in the Adventist Health Study to be negatively associated with risk of colon cancer (23). New data suggest that legume intake is also associated with a moderate reduction in the risk of prostate cancer (33). In Western society, vegans also consume substantially more tofu and other soy products than do omnivores (14, 16). Consumption of isoflavone-containing soy products during childhood and adolescence protects women against the risk of breast cancer later in life (34), whereas a high childhood dairy intake has been associated with an elevated risk of colorectal cancer in adulthood (35). Cancer risk in vegans may be altered because vegans consume soy beverages rather than dairy beverages. Data from the Adventist Health Study showed that consumption of soy milk by vegetarians protected them against prostate cancer (36), whereas in other studies the use of dairy was associated with an increased risk of prostate cancer (25, 37–39).

Further research is needed to explore the relation between consuming plant-based diets and risk of cancer because there are many unanswered questions about how diet and cancer are connected. To date, epidemiologic studies have not provided convincing evidence that a vegan diet provides significant protection against cancer. Although plant foods contain many chemopreventive factors, most of the research data comes from cellular biochemical studies.

Bone health

Cross-sectional and longitudinal population-based studies published within the past 2 decades suggest no differences in bone mineral density (BMD), for both trabecular and cortical bone, between omnivores and lactoovovegetarians (40). More recent studies with postmenopausal Asian women showed spine or hip BMD was significantly lower in long-term vegans (41, 42). Those Asian women, who were vegetarian for religious reasons, had low intakes of protein and calcium. An inadequate protein and low calcium intake has been shown to be associated with bone loss and fractures at the hip and spine in the elderly (43, 44). Adequate calcium intake may be a problem for vegans. Although lactoovovegetarians generally consume adequate amounts of calcium, vegans typically fall short of the recommended daily intake for calcium (8, 45, 46). Results from the EPIC-Oxford study provide good evidence that the risk of bone fractures for vegetarians was similar to that of omnivores (46). The higher risk of bone fracture seen in vegans appears to be a consequence of a lower mean calcium intake. No difference was observed between the fracture rates of the vegans who consumed $>$525 mg calcium/d and the omnivore fracture rates (46).

Bone health depends on more than just protein and calcium intakes. Research has shown that bone health is also influenced by nutrients such as vitamin D, vitamin K, potassium, and magnesium and by foods such as soy and fruit and vegetables (47–50). Vegan diets do well in providing a number of those important substances. The maintenance of acid-base balance is critical for bone health. A drop in extracellular pH stimulates bone resorption (51), because bone calcium is used to buffer the pH drop. An acidforming diet, therefore, increases urinary calcium excretion (52). However, a diet rich in fruit and vegetables that is typical of a vegan diet has a positive effect on the calcium economy and markers of bone metabolism in men and women (49). The high potassium and magnesium content of fruit and vegetables provides an alkaline ash, which inhibits bone resorption (53). Higher intakes of potassium are associated with greater BMD of the femoral neck and lumbar spine of premenopausal women (54).

Blood concentrations of undercarboxylated osteocalcin, a sensitive marker of vitamin K status, is considered an indicator of hip fracture (55) and a predictor of BMD (56). Results from 2 large, prospective cohort studies support an association between vitamin K intake and relative risk of hip fracture. In the Nurses' Health Study, middle-aged women consuming the most vitamin K had the lowest risk of hip fracture. Risk of hip fracture was decreased 45% for $\geq$1 servings/d of green leafy vegetables (the main vitamin K source) compared with $\leq$1 serving/wk (57). In the Framingham Heart Study, elderly men and women in the highest quartile of vitamin K intake had a 65% decreased risk of hip fracture than did those in the lowest quartile (58).

In addition to a high intake of fruit and vegetables, vegans also tend to have a high intake of tofu and other soy products (14, 16). Soy isoflavones are suggested to have a beneficial effect on bone health in postmenopausal women (50). In a meta-analysis of 10 randomized controlled trials, soy isoflavones showed a significant benefit to spine BMD of menopausal women (59). In another meta-analysis, soy isoflavones significantly inhibited bone resorption and stimulated bone formation compared with placebo (60). In a randomized clinical trial lasting 24 mo involving osteopenic postmenopausal women, increases in BMD of both lumbar spine and femoral neck were substantially greater with the soy isoflavone, genistein, than with placebo (61).

As long as the calcium and vitamin D intake of vegans is adequate, their bone health is probably not an issue because their diet contains an ample supply of other protective factors for bone health. However, more studies are needed to provide more definitive data on the bone health of vegans.

POTENTIAL NUTRITIONAL SHORTFALLS

To obtain a nutritionally adequate diet, the consumer must first have an appropriate knowledge of what constitutes a nutritionally adequate diet. Second, accessibility is important, ie, the availability of certain foodstuffs and foods fortified with key nutrients that are otherwise lacking in the diet. This accessibility will vary greatly, depending on the geographic region of the world, because different countries have different fortification laws. The following section deals with nutrients of concern in the vegan diet. The problem of insufficient calcium has already been discussed in the section on bone health.

n–3 Polyunsaturated fat

Diets that do not include fish, eggs, or sea vegetables (seaweeds) generally lack the long-chain n–3 fatty acids, eicosapentaenoic acid (EPA; 20:5n$-$3) and docosahexaenoic acid (DHA; 22:6n$-$3), which are important for cardiovascular health as well as eye and brain functions. The plant-based n–3 fatty acid α-linolenic acid (ALA; 18:3n$-$3) can be converted into EPA and DHA, albeit with a fairly low efficiency (62, 63). Compared with nonvegetarians, vegetarians, and especially vegans, tend to have lower blood concentrations of EPA and DHA (64). However, vegans can obtain DHA from microalgae supplements containing DHA, as well as from foods fortified with DHA. However, EPA can be obtained from the retroconversion of DHA in the body. The oil from brown algae (kelp) has also been identified as a good source of EPA.

The new Dietary Reference Intakes recommend intakes of 1.6 and 1.1 g ALA/d for men and women, respectively, which accounts for $<$1% of the daily calories. Presently, the intake of EPA plus DHA in the United States is only 0.1–0.2 g/d, with the DHA intake being $\approx$2–3 times the intake of EPA (65). Vegans should be able to easily reach the n–3 fatty acid requirements by including regular supplies of ALA-rich foods in their diet and also DHA-fortified foods and supplements. However, DHA supplements should be taken with caution. Although they can lower plasma triacylglycerol, they can raise total and LDL cholesterol (66, 67), cause excessively prolonged bleeding times, and impair immune responses (65).

Vitamin D

In the EPIC-Oxford study, vegans had the lowest mean intake of vitamin D (0.88 μg/d), a value one-fourth the mean intake of omnivores (8). For a vegan, vitamin D status depends on both sun exposure and the intake of vitamin D-fortified foods. Those living in areas of the world without fortified foods would need to consume a vitamin D supplement. Living at high latitudes can also affect one's vitamin D status, because sun exposure in that region is inadequate for several months of the year (68). Those who are dark skinned, elderly, who extensively cover their body with clothing for cultural reasons, and who commonly use sunscreen are at an increased risk of vitamin D deficiency (45). Another matter of concern for vegans is that vitamin D_2, the form of vitamin D acceptable to vegans, is substantially less bioavailable than the animal-derived vitamin D_3 (69).

In Finland, the dietary intake of vitamin D in vegans was insufficient to maintain serum 25-hydroxyvitamin D and parathyroid hormone concentrations within normal ranges in the winter, which appeared to have a negative effect on long-term BMD (28). Throughout the year serum 25-hydroxyvitamin D concentrations were lower and parathyroid hormone higher in vegan women than in omnivores and other vegetarians. BMD in the lumbar region of the spine was 12% lower in vegans than in omnivores.

Iron

Heme iron absorption is substantially higher than non-heme iron from plant foods. However, hemoglobin concentrations and the risk of iron deficiency anemia are similar for vegans compared with omnivores and other vegetarians (70). Vegans often consume large amounts of vitamin C–rich foods that markedly improve the absorption of the nonheme iron. Serum ferritin concentrations are lower in some vegans, whereas the mean values tend to be similar to the mean values of other vegetarians but lower than the mean value for omnivores (71). The physiologic significance of low serum ferritin concentrations is uncertain at this time.

Vitamin B-12

Compared with lactoovovegetarians and omnivores, vegans typically have lower plasma vitamin B-12 concentrations, higher prevalence of vitamin B-12 deficiency, and higher concentrations of plasma homocysteine (72). Elevated homocysteine has been considered a risk factor for CVD (73) and osteoporotic bone fractures (74). Vitamin B-12 deficiency can produce abnormal neurologic and psychiatric symptoms that include ataxia, psychoses, paresthesia, disorientation, dementia, mood and motor disturbances, and difficulty with concentration (75). In addition, children may experience apathy and failure to thrive, and macrocytic anemia is a common feature at all ages.

Zinc

Vegetarians are often considered to be at risk for zinc deficiency. Phytates, a common component of grains, seeds, and legumes, binds zinc and thereby decreases its bioavailability. However, a sensitive marker to measure zinc status in humans has not been well established, and the effects of marginal zinc intakes are poorly understood (76). Although vegans have lower zinc intake than omnivores, they do not differ from the nonvegetarians in functional immunocompetence as assessed by natural killer cell cytotoxic activity (14). It appears that there may be facilitators of zinc absorption and compensatory mechanisms to help vegetarians adapt to a lower intake of zinc (77).

DIETARY RECOMMENDATIONS FOR OPTIMAL VEGAN DIETS

1) To avoid B-12 deficiency, vegans should regularly consume vitamin B-12–fortified foods, such as fortified soy and rice beverages, certain breakfast cereals and meat analogs, and B-12–fortified nutritional yeast, or take a daily vitamin B-12 supplement. Fermented soy products, leafy vegetables, and seaweed cannot be considered a reliable source of active vitamin B-12. No unfortified plant food contains any significant amount of active vitamin B-12.

2) To ensure adequate calcium in the diet, calcium-fortified plant foods should be regularly consumed in addition to consuming the traditional calcium sources for a vegan (green leafy vegetables, tofu, tahini). The calcium-fortified foods include ready-to-eat cereals, calcium-fortified soy and rice beverages, calcium-fortified orange and apple juices, and other beverages. The bioavailability of the calcium carbonate in the soy beverages and the calcium citrate malate in apple or orange juice is similar to that of the calcium in milk (78, 79). Tricalcium phosphate–fortified soy milk was shown to have a slightly lower calcium bioavailability than the calcium in cow milk (78).

3) To ensure an adequate vitamin D status, especially during the winter, vegans must regularly consume vitamin D–fortified foods such as soy milk, rice milk, orange juice, breakfast cereals, and margarines that are fortified with vitamin D. Where fortified foods are unavailable, a daily supplement of 5–10 μg vitamin D would be necessary. The supplement would be highly desirable for elderly vegans.

4) A vegan should regularly consume plant foods naturally rich in the n–3 fatty acid ALA, such as ground flaxseed, walnuts, canola oil, soy products, and hemp seed–based beverages. In addition, it is recommended that vegans consume foods that are fortified with the long-chain n–3 fatty acid DHA, such as some soy milks and cereal bars. Those with increased requirements of long-chain n–3 fatty acids, such as pregnant and lactating women, would benefit from using DHA-rich microalgae supplements.

5) Because of the high phytate content of a typical vegan diet, it is important that a vegan consume foods that are rich in zinc, such as whole grains, legumes, and soy products, to provide a sufficient zinc intake. Benefit could also be obtained by vegans consuming fortified ready-to-eat cereals and other zinc-fortified foods.

A more comprehensive list of eating guidelines for vegans is available elsewhere (80).

FURTHER RESEARCH NEEDED

The term *vegetarian* is often used to describe a whole range of diets practiced with varying degrees of restriction, making it a challenge to meaningfully compare and contrast the health benefits of various vegetarian diets. Although preliminary data are valuable, more scientific studies on vegans are needed to get a clearer picture of their health status (7, 11). Current data show that vegans have a lower risk of heart disease than do omnivores and other vegetarians, but there are too few studies on other risk factors for definitive conclusions. One small pilot trial has shown that a vegan diet improves glycemic control in individuals with type 2 diabetes (81), but more studies are needed that look at the effects of a vegan diet on the risk of diabetes, as well as cancer. On the basis of our present knowledge, vegans do not appear likely to have any significant advantages over other vegetarians about chronic disease patterns (11). The vegan studies that do exist often involve only a small number of subjects. More studies are also needed with long-term vegans because the health advantages appear more clearly defined when a person has been following a plant-based diet for $>$5 y (82). Research is also needed to investigate whether the age at which a vegan diet is adopted has any influence on health outcomes.

SUMMARY

Vegans are thinner, have lower serum cholesterol and blood pressure, and enjoy a lower risk of CVD. BMD and the risk of bone fracture may be a concern when there is an inadequate intake of calcium and vitamin D. Where available, calcium- and vitamin D–fortified foods should be regularly consumed. There is a need for more studies on the relation between vegan diets and risk of cancer, diabetes, and osteoporosis. Vitamin B-12 deficiency is a potential problem for vegans, so that the use of vitamin B-12–fortified foods or supplements are essential. To optimize the n–3 fatty acid status of vegans, foods rich in ALA, DHA-fortified foods, or DHA supplements should be regularly consumed. Vegans generally have an adequate iron intake and do not experience anemia more frequently than others. Typically, vegans can avoid nutritional problems if appropriate food choices are made. Their health status appears to be at least as good as other vegetarians, such as lactoovovegetarians. (Other articles in this supplement to the Journal include references 83–109.)

The author had no financial disclosures to report.

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