

Position of the American Dietetic Association and Dietitians of Canada: Vegetarian Diets

Abstract

It is the position of the American Dietetic Association and Dietitians of Canada that appropriately planned vegetarian diets are healthful, nutritionally adequate, and provide health benefits in the prevention and treatment of certain diseases. Approximately 2.5% of adults in the United States and 4% of adults in Canada follow vegetarian diets. A vegetarian diet is defined as one that does not include meat, fish, or fowl. Interest in vegetarianism appears to be increasing, with many restaurants and college foodservices offering vegetarian meals routinely. Substantial growth in sales of foods attractive to vegetarians has occurred and these foods appear in many supermarkets.

This position paper reviews the current scientific data related to key nutrients for vegetarians including protein, iron, zinc, calcium, vitamin D, riboflavin, vitamin B-12, vitamin A, n-3 fatty acids, and iodine. A vegetarian, including vegan, diet can meet current recommendations for all of these nutrients. In some cases, use of fortified foods or supplements can be helpful in meeting recommendations for individual nutrients. Well-planned vegan and other types of vegetarian diets are appropriate for all stages of the life-cycle including during pregnancy, lactation, infancy, childhood, and adolescence. Vegetarian diets offer a number of nutritional benefits including lower levels of saturated fat, cholesterol, and animal protein as well as higher levels of carbohydrates, fibre, magnesium, potassium, folate, antioxidants such as vitamins C and E, and phytochemicals. Vegetarians have been reported to have lower body mass indices than non-vegetarians, as well as lower rates of death from ischemic heart disease, lower blood cholesterol levels, lower blood pressure, and lower rates of hypertension, type 2 diabetes, and prostate and colon cancer. While a number of federally funded and institutional feeding programs can accommodate vegetarians, few have foods suitable for vegans at this time. Because of the variability of dietary practices among vegetarians, individual assessment of dietary intakes of vegetarians is required. Dietetics professionals have a responsibility to support and encourage those who express an interest in consuming a vegetarian diet. They can play key roles in educating vegetarian clients about food sources of specific nutrients, food purchase and preparation, and any dietary modifications that may be necessary to meet individual needs. Menu planning for vegetarians can be simplified by use of a food guide that specifies food groups and serving sizes.

(Can J Diet Prac Res 2003; 64:62-81)

Résumé

L'American Dietetic Association et les Diététistes du Canada soutiennent que les régimes végétariens planifiés de façon appropriée sont sains, adéquats sur le plan nutritionnel et bénéfiques dans la prévention et le traitement de certaines maladies. Parmi les adultes, environ 2,5 % aux États-Unis et 4 % au Canada observent un régime végétarien, qu'on définit comme une alimentation qui n'inclut ni viande, ni poisson ni volaille. L'intérêt envers le végétarisme semble s'accroître, et de nombreux restaurants et services alimentaires d'établissements d'enseignement offrent régulièrement des mets végétariens. On constate également une croissance substantielle des ventes d'aliments recherchés par les végétariens, notamment dans de nombreux supermarchés.

Cet exposé de position présente les données scientifiques actuelles relatives aux nutriments clés pour les végétariens : protéines, fer, zinc, calcium, vitamine D, riboflavine, vitamine B₁₂, vitamine A, acides gras n-3 et iode. Les régimes végétariens, y compris les régimes végétaliens, peuvent satisfaire aux recommandations actuelles pour tous ces nutriments. Dans certains cas, l'usage d'aliments enrichis ou de suppléments peut être utile. Les régimes végétaliens et les autres types de régimes végétariens bien planifiés conviennent à toutes les étapes de la vie, entre autres la grossesse, l'allaitement, la petite enfance, l'enfance et l'adolescence. Les régimes végétariens apportent de nombreux bienfaits nutritionnels, notamment des niveaux plus faibles de gras saturés, de cholestérol et de protéines animales ainsi que des niveaux plus élevés de glucides, fibres, magnésium, potassium, folate, antioxydants telles les vitamines C et E et substances phytochimiques. Les végétariens présenteraient des indices de masse corporelle et des taux de mortalité attribuable à la cardiopathie ischémique plus faibles que les non-végétariens; ils auraient aussi des niveaux de cholestérol sanguin, une pression sanguine et des taux d'hypertension, de diabète de type 2 et de cancers de la prostate et du côlon plus faibles. De nombreux programmes alimentaires subventionnés par le fédéral et beaucoup de services alimentaires peuvent satisfaire les végétariens, mais peu d'entre eux, les végétaliens. La diversité des pratiques diététiques des végétariens impose l'évaluation individuelle des apports alimentaires. Les professionnels de la diététique doivent soutenir et encourager ceux qui souhaitent consommer un régime végétarien. Ils peuvent jouer un rôle clé dans l'éducation de leurs clients végétariens quant aux sources alimentaires des nutriments, à l'achat et à la préparation des aliments et à toute modification alimentaire rendue nécessaire par les besoins individuels. La planification des menus végétariens peut être simplifiée par l'usage d'un guide alimentaire où figurent les groupes d'aliments et les grosseurs de portions.

(Rev can prat rech diétét 2003; 64:62-81)

POSITION STATEMENT/ÉNONCÉ DE POSITION

It is the position of the American Dietetic Association and Dietitians of Canada that appropriately planned vegetarian diets are healthful, nutritionally adequate, and provide health benefits in the prevention and treatment of certain diseases.

L'American Dietetic Association et les Diététistes du Canada soutiennent que les régimes végétariens planifiés de façon appropriée sont sains, adéquats sur le plan nutritionnel et bénéfiques dans la prévention et le traitement de certaines maladies.

VEGETARIANISM IN PERSPECTIVE

A vegetarian is a person who does not eat meat, fish, or fowl or products containing these foods. The eating patterns of vegetarians may vary considerably. The lacto-ovo-vegetarian eating pattern is based on grains, vegetables, fruits, legumes, seeds, nuts, dairy products, and eggs, but excludes meat, fish, and fowl. The lacto-vegetarian excludes eggs as well as meat, fish, and fowl. The vegan, or total vegetarian, eating pattern is similar to the lacto-vegetarian pattern with the additional exclusion of dairy and other animal products. Even within these patterns, considerable variation may exist in the extent to which animal products are avoided.

People choosing macrobiotic diets are frequently identified as following a vegetarian diet. The macrobiotic diet is based largely on grains, legumes, and vegetables. Fruits, nuts, and seeds are used to a lesser extent. Some people following a macrobiotic diet are not truly vegetarian because they use limited amounts of fish. Some "self-described" vegetarians, who are not vegetarians at all, will eat fish, chicken, or even meat (1,2). Some research studies have identified these "self-described" vegetarians as semi-vegetarians and have defined semi-vegetarian as occasional meat-eaters who predominately practice a vegetarian diet (3) or those who eat fish and poultry but less than 1 time per week (4). Individual assessment is required to accurately evaluate the nutritional quality of the diet of a vegetarian or someone who says that they are vegetarian.

Common reasons for choosing a vegetarian diet include health considerations, concern for the environment, and animal welfare factors (5,6). Vegetarians also cite economic reasons, ethical considerations, world hunger issues, and religious beliefs as their reasons for following their chosen eating pattern.

Consumer trends

In 2000, approximately 2.5% of the U.S. adult population (4.8 million people) consistently followed a vegetarian diet and affirmed that they never ate meat, fish, or poultry (7). Slightly less than 1% of those polled were vegans (7). According to this poll, vegetarians are most likely to live on the east or west coast, in large cities and to be female. Approximately 2% of six- to 17-year-olds in the United States are vegetarians and around 0.5% of this age group are vegan (8). According to a 2002 survey (9), about 4% of Canadian adults are vegetarian; this represents an estimated 900,000 people. Factors that may affect the number of vegetarians in the United States and Canada in the future include an increased interest in vegetarianism and the arrival of immigrants from countries where vegetarianism is commonly practiced (10). Twenty to 25% of adults in the United States report that they eat four or more meatless meals weekly, or "usually or sometimes maintain a vegetarian diet", suggesting an interest in vegetarianism (11). Additional evidence for the increased interest in vegetarianism includes the emergence of animal rights/ethics courses on college and university

campuses; the proliferation of Web sites, magazines and newsletters, and cookbooks with a vegetarian theme, and the public's attitude toward ordering a vegetarian meal when eating away from home. More than 5% of those surveyed in 1999 said they always order a vegetarian meal when they eat out; close to 60% "sometimes, often, or always" order a vegetarian item at a restaurant (12).

Restaurants have responded to this interest in vegetarianism. The National Restaurant Association reports that eight out of 10 restaurants in the United States with table service offer vegetarian entrees (13). Fast food restaurants are beginning to offer salads, veggie burgers, and other vegetarian options. Many college students consider themselves vegetarians. In response to this, most university foodservices offer vegetarian options (14).

There has also been a growth in professional interest in vegetarian nutrition. The number of articles in the scientific literature related to vegetarianism has increased from fewer than ten articles per year in the late 1960s to 76 articles per year in the 1990s (15). In addition, the main focus of the articles is changing. Twenty-five or more years ago, articles primarily had themes questioning the nutritional adequacy of vegetarian diets. More recently, the theme has been the use of vegetarian diets in the prevention and treatment of disease. More articles feature epidemiological studies and fewer reports are case studies and letters to the editor (15).

There is a growing appreciation for the benefits of plant-based diets, defined as diets that include generous amounts of plant foods and limited amounts of animal foods. The American Institute for Cancer Research and the World Cancer Research Fund call for choosing predominantly plant-based diets rich in a variety of vegetables and fruits, legumes, and minimally processed starchy staple foods and limiting red meat consumption, if red meat is eaten at all (16). The American Cancer Society recommends choosing most food from plant sources (17). The American Heart Association recommends choosing a balanced diet with an emphasis on vegetables, grains, and fruits (18) while the Heart and Stroke Foundation of Canada recommends using grains and vegetables instead of meat as the centerpiece of meals (19). The Unified Dietary Guidelines developed by the American Cancer Society, the American Heart Association, the National Institutes of Health, and the American Academy of Pediatrics call for a diet based on a variety of plant foods including grain products, vegetables and fruits to reduce risk of major chronic diseases (20).

New product availability

The U.S. market for vegetarian foods (foods like meat analogs, nondairy milks, and vegetarian entrees that directly replace meat or other animal products) was estimated to be \$1.5 billion in 2002, up from \$310 million in 1996 (21). This market is expected to nearly double by 2006 to \$2.8 billion (21).

Canadian sales of meat analogs more than tripled between 1997 and 2001 (22).

The ready availability of new products, including fortified foods and convenience foods, would be expected to have a marked impact on nutrient intake of vegetarians. Fortified foods such as soymilks, meat analogs, juices, and breakfast cereals can add substantially to vegetarians' intakes of calcium, iron, zinc, vitamin B-12, vitamin D, and riboflavin. Vegetarian convenience foods including veggie burgers and veggie dogs, frozen entrees, meals in a cup, and soymilk can make it much simpler to be a vegetarian today than in the past.

Vegetarian foods are readily available, both in supermarkets and in natural foods stores. About half of vegetarian foods volume is sold through supermarkets and about half through natural foods stores (21). Three-fourths of soymilk sales take place in supermarkets (21).

Public policy statements and vegetarian diets

The United States Dietary Guidelines (23) state, "Vegetarian diets can be consistent with the *Dietary Guidelines for Americans*, and meet Recommended Dietary Allowances for nutrients." They give recommendations on meeting nutrient requirements for those who choose to avoid all or most animal products. Some have said that implementation of the Dietary Guidelines can best be achieved by use of vegetarian and plant-rich diets (24). National food guides include some vegetarian options. Foods commonly eaten by vegetarians such as legumes, tofu, soyburgers, and soymilk with added calcium are included in a table accompanying the USDA's Food Guide Pyramid (23). Canada's Food Guide to Healthy Eating can be used by lacto and lacto-ovo-vegetarians (25). Health Canada has stated that well-planned vegetarian diets are supportive of good nutritional status and health (26).

HEALTH IMPLICATIONS OF VEGETARIANISM

Vegetarian diets offer a number of advantages including lower levels of saturated fat, cholesterol, and animal protein and higher levels of carbohydrates, fibre, magnesium, boron, folate, antioxidants such as vitamins C and E, carotenoids, and phytochemicals (27-30). Some vegans may have intakes for vitamin B-12, vitamin D, calcium, zinc, and occasionally riboflavin that are lower than recommended (27,29,31).

NUTRITION CONSIDERATIONS FOR VEGETARIANS

Protein

Plant protein can meet requirements when a variety of plant foods is consumed and energy needs are met. Research indicates that an assortment of plant foods eaten over the course of a day can provide all essential amino acids and ensure adequate nitrogen retention and use in healthy adults; thus complementary proteins do not need to be consumed at the same meal (32).

Estimates of protein requirements of vegans vary, depending to some degree on diet choices (33). A recent meta-analysis of nitrogen balance studies found no significant difference in protein needs due to the source of dietary protein (34,35). Based primarily on the lower digestibility of plant proteins, other groups have suggested that protein requirements of vegans

may be increased by 30-35% for infants up to the age of two years, 20-30% for two- to six-year-olds, and 15-20% for those 6 years and older, in comparison with those of non-vegetarians (36).

The quality of plant proteins varies. Based on the protein digestibility corrected amino acid score (PDCAAS), which is the standard method for determining protein quality, isolated soy protein can meet protein needs as effectively as animal protein, while wheat protein eaten alone, for example, may be 50% less usable than animal protein (37). Nutrition care professionals should be aware that protein needs might be higher than the RDA in vegetarians whose dietary protein sources are mainly those that are less well digested, such as some cereals and legumes.

Cereals tend to be low in lysine, an essential amino acid. This may be relevant when evaluating diets of individuals who do not consume animal protein sources and are relatively low in protein (35). Dietary adjustments such as the use of more beans and soy products in place of other protein sources that are lower in lysine, or an increase in dietary protein from all sources can ensure an adequate intake of lysine.

Though some vegan women have protein intakes that are marginal, typical protein intakes of lacto-ovo-vegetarians and of vegans appear to meet and exceed requirements (29). Athletes can also meet their protein needs on plant-based diets (38,39).

Iron

Plant foods contain only nonheme iron, which is more sensitive than heme iron to both inhibitors and enhancers of iron absorption. Inhibitors of iron absorption include phytate, calcium, teas including some herb teas, coffee, cocoa, some spices, and fibre (40). Vitamin C and other organic acids found in fruits and vegetables can enhance iron absorption and can help to reduce effects of phytate (41-43). Studies show that iron absorption would be significantly reduced if a diet were to be high in inhibitors and low in enhancers. Recommended iron intakes for vegetarians are 1.8 times those of non-vegetarians because of lower bioavailability of iron from a vegetarian diet (44).

The main inhibitor of iron absorption in vegetarian diets is phytate. Because iron intake increases as phytate intake increases, effects on iron status are somewhat less than might be expected. Fibre appears to have a minor effect on iron absorption (45,46). Vitamin C, consumed at the same time as the iron source, can help to reduce the inhibitory effects of phytate (42,43) and some research links high vitamin C intake to improved iron status (47,48). The same is true for organic acids in fruits and vegetables (41). The higher intakes of vitamin C and of vegetables and fruits by vegetarians can favourably impact iron absorption (2). Some food preparation techniques such as soaking and sprouting beans, grains, and seeds, can hydrolyze phytate (49-51) and may improve iron absorption (42,51,52). Leavening of breads hydrolyzes phytate and enhances iron absorption (49-51,53,54). Other fermentation processes, such as those used to make soyfoods like miso and tempeh, may also make iron more available (55), although not all research supports this. Whereas many studies of iron absorption have been short-term, there is evidence that adaptation to low intakes takes place over the longer term,

Table 1
Vegetarian food sources of nutrients

Nutrient	Amount per serving	Nutrient	Amount per serving
IRON	mg	IRON	mg
Soyfoods		Mung bean sprouts	0.8
Soybeans, cooked, 1/2 c (125 mL)	4.4	Mushrooms	1.4
Soybeans, dry roasted, (soynuts), 1/4 c (60 mL)	1.7	Potato, baked, with skin, 1 medium (173 g)	2.3
Soymilk 1/2 c (125 mL)	0.4-1.0	Tomato juice	0.7
Tempeh, 1/2 c (83 g)	2.2	Turnip greens	0.6
Tofu, firm, 1/2 c (126 g)	6.6	Other Foods	
Veggie “meats”, fortified, 1 oz (28 g)	0.5-1.9	Blackstrap molasses, 1 Tbsp (15 mL)	3.5
Legumes (cooked, 1/2 c/125 mL)		ZINC	mg
Adzuki beans	2.3	Soyfoods	
Baked beans, canned, vegetarian	1.7	Soybeans, cooked, 1/2 c (250 mL)	1.0
Black beans	1.8	Soybeans, dry roasted, 1/2 c (250 mL)	4.2
Chickpeas, garbanzo beans	2.4	Soymilk, 1/2 c (125 mL)	0.3
Great northern beans	1.9	Soymilk, fortified, 1/2 c (125 mL)	0.5-1.0
Kidney beans	2.6	Tempeh, 1/2 c (83 g)	0.9
Lentils	3.3	Tofu, firm, 1/2 c (126 g)	1.0
Lima beans	2.2	Veggie “meats”, fortified, 1 oz (42 g)	1.2-2.3
Navy beans	2.3	Legumes (cooked, 1/2 c/125 mL)	
Pinto beans	2.2	Adzuki beans	2.0
Nuts, Peanuts, Seeds, and Their Butters		Baked beans, canned, vegetarian	1.8
Almonds, 1/4 c (60 mL)	1.5	Black beans	1.0
Cashews 1/4 c (60 mL)	2.1	Chickpeas, garbanzo beans	1.3
Peanut butter, 2 Tbsp (30 mL)	0.6	Great northern beans	0.8
Peanuts, dry roast, 1/4 c (60 mL)	0.8	Kidney beans	0.9
Pumpkin and squash seeds, dried, 1/4 c (60 mL)	5.2	Lima beans	0.9
Sesame tahini, 2 Tbsp (30 mL)	2.7	Lentils	1.2
Sunflower seeds, toasted, 1/4 c (60 mL)	2.3	Navy beans	2.3
Breads, Cereals and Grains		Nuts, Peanuts, Seeds, and Their Butters	
Barley, pearled, cooked, 1/2 c (125 mL)	1.0	Almonds, 1/4 c (60 mL)	1.2
Cereal, ready-to-eat, fortified, 1 oz (28 g)	2.1-18	Cashews, 1/4 c (60 mL)	1.9
Cream of Wheat, cooked, 1/2 c (125 mL)	5.1	Peanut butter, 2 Tbsp (30 mL)	0.9
Oatmeal, instant, fortified, cooked, 1/2 c (125 mL)	4.2	Peanuts, dry roast, 1/4 c (60 mL)	1.2
Oatmeal, regular, quick or instant, cooked, 1/2 c (125 mL)	1.6	Pumpkin and squash seeds, dried, 1/4 c (60 mL)	2.6
Quinoa, cooked, 1/2 c (125 mL)	2.1	Sesame tahini, 2 Tbsp (30 mL)	1.4
Wheat germ, 2 Tbsp (14 g)	0.9	Sunflower seeds, toasted, 1/4 c (60 mL)	1.8
Whole wheat or white enriched bread, 1 slice (28 g)	0.9	Breads, Cereals, and Grains	
Fruits (dried, 1/4 c/60 mL)		Barley, pearled, cooked, 1/2 c (125 mL)	0.6
Apricots	1.5	Cereal, ready-to-eat, fortified, 1 oz (28 g)	0.7-15
Currants	1.2	Quinoa, cooked, 1/2 c (125 mL)	0.8
Figs	1.1	Wheat germ, 2 Tbsp (14 g)	1.8
Prunes	1.1	Whole wheat bread, 1 slice (28 g)	0.5
Raisins	1.1	Vegetables (cooked, 1/2 cup/125 mL)	
Vegetables (cooked, 1/2 c/125 mL unless indicated otherwise)		Mushrooms	0.7
Bok choy (Chinese cabbage, pak choi)	0.9	Peas	1.0
Broccoli	0.7	Dairy Foods and Eggs	
Green or yellow beans	0.8	Cow’s milk, 1/2 c (125 mL)	0.5
Kale	0.6	Cheddar cheese, 3/4 oz (21 g)	0.7
		Egg, large, 1 (50 g)	0.5
		Yogurt, 1/2 c (125 mL)	0.8-1.1

Table 1 (*continued*)
Vegetarian food sources of nutrients

Nutrient	Amount per serving	Nutrient	Amount per serving
CALCIUM	mg	VITAMIN D	mcg
Soyfoods		Cereals, ready-to-eat, fortified, 1 oz (28 g)	0.5-1
Cultured soy yogurt, fortified, 1/2 c (125 mL)	367	Egg yolk, large, 1 (17 g)	0.6
Soybeans, cooked, 1/2 c (125 mL)	88	Cow's milk, fortified, 1/2 c (125 mL)	1.2-1.3
Soybeans, dry roasted, (soynuts), 1/4 c (60 mL)	60	Soymilk or other nondairy milk, fortified, 1/2 c (125 mL)	0.5-1.5
Soybeans, green, 1/2 c (125 mL)	130	RIBOFLAVIN	mg
Soymilk, fortified, 1/2 c (125 mL)	100-159	Almonds, 1/4 c (60 mL)	0.3
Tofu, firm, calcium-set, 1/2 c (126 g)	120-430	Cereal, ready-to-eat, fortified, 1 oz (28 g)	0.2-1.7
Tempeh, 1/2 c (83 g)	92	Cow's milk, whole, 2% or skim, 1/2 c (125 mL)	0.2
Legumes (cooked, 1/2 c/125 mL)		Yogurt, 1/2 c (125 mL)	0.3
Black beans	46	Egg, large, 1 (50 g)	0.6
Chickpeas, garbanzo beans	40	Mushrooms, cooked, 1/2 c (125 mL)	0.2
Great northern or navy beans	60-64	Nutritional yeast mini-flakes, 1 Tbsp (3 g)	1.9
Pinto beans	41	Soymilk, fortified, 1/2 c (125 mL)	0.2
Vegetarian baked beans	64	VITAMIN B-12	mcg
Nuts, Seeds and Their Butters		Cereals, ready-to-eat, fortified, 1 oz (28 g)	0.6-6.0
Almonds, 1/4 c (60 mL)	88	Cow's milk, 1/2 c (125 mL)	0.4-0.5
Almond butter, 2 Tbsp (30 mL)	86	Egg, large, 1 (50 g)	0.5
Sesame tahini, 2 Tbsp (30 mL)	128	Nutritional yeast (Red Star Vegetarian Support Formula), mini-flakes, 1 Tbsp (3 g)	1.5
Breads, Cereals and Grains		Soymilk or other non-dairy milks, fortified, 1/2 c (125 mL)	0.4-1.6
Cereal, ready-to-eat, fortified, 1 oz (28 g)	55-315	Veggie "meats", fortified, 1 oz (28 g)	0.5-1.2
Fruits		LINOLENIC ACID	g
Figs, dried, 5	137	Canola oil, 1 Tbsp (15 mL)	1.3-1.6
Orange, 1 large	74	Flax seed, ground, 1 Tbsp (15 mL)	1.9-2.2
Orange juice, fortified, 1/2 c (125 mL)	150	Flaxseed oil, 1 tsp (5 mL)	2.7
Vegetables (cooked, 1 c/250 mL)		Soybean oil, 1 Tbsp (15 mL)	0.9
Bok choy (Chinese cabbage, pak choi)	167-188	Soybeans, cooked, 1/2 c (125 mL)	1.0
Broccoli	79	Tofu, 1/2 c (126 g)	0.7
Collard greens	239	Walnuts, 1/4 c (60 mL)	2.7
Kale	99	Walnut oil, 1 Tbsp (30 mL)	1.4-1.7
Kale, Scotch	181		
Mustard greens	109		
Okra	107		
Turnip greens	208		
Other Foods			
Blackstrap Molasses, 1 Tbsp (15 mL)	172		
Dairy Products			
Cow's milk, 1/2 c (125 mL)	137-158		
Cheddar cheese, 3/4 oz (21 g)	153		
Yogurt, plain, 1/2 c (125 mL)	137-230		

Sources: Package information and data from: U.S. Department of Agriculture, Agricultural Research Service. 2002. USDA Nutrient Database for Standard Reference, Release 15. Nutrient Data Laboratory Home Page, <http://www.nal.usda.gov/fnic/foodcomp>; Bhatti RS. Nutrient composition of whole flaxseed and flaxseed meal. In: Cunnane SC, Thompson LU, eds. *Flaxseed and Human Nutrition*. Champaign, Ill: AOCS Press; 1995:22-42.

and involves both increased absorption and decreased losses (56,57). It is likely that iron needs will depend on the make-up of the overall diet and be significantly lower for some vegetarians than for others.

Studies typically show iron intake by vegans to be higher than that of lacto-ovo-vegetarians and of non-vegetarians, and most

studies show iron intake by lacto-ovo-vegetarians to be higher than that of non-vegetarians (29). Iron sources are shown in Table 1. Incidence of iron deficiency anemia among vegetarians is similar to that of non-vegetarians (29,31,58). Although vegetarian adults have lower iron stores than non-vegetarians, their serum ferritin levels are usually within the normal range (58-62).

Zinc

Because phytate binds zinc, and animal protein is believed to enhance zinc absorption, total zinc bioavailability appears to be lower in vegetarian diets (63). Also, some vegetarians have diets that are significantly below recommended intakes for zinc (27,29,64,65). Although overt zinc deficiency has not been seen in western vegetarians, the effects of marginal intakes are poorly understood (66). Zinc requirements for vegetarians whose diets are high in phytate may exceed the RDA (44). Zinc sources are shown in Table 1.

Compensatory mechanisms may help vegetarians adapt to lower intakes of zinc (65,67). Some food preparation techniques, such as soaking and sprouting beans, grains and seeds, and leavening bread, can reduce binding of zinc by phytate and increase zinc bioavailability (49,50,68).

Calcium

Calcium is present in many plant foods and fortified foods (see Table 1). Low-oxalate greens (bok choy, broccoli, Chinese/Napa cabbage, collards, kale, okra, turnip greens) provide calcium with high bioavailability (49-61%), in comparison with calcium-set tofu, fortified fruit juices, and cow's milk (bioavailability in the range of 31-32%) and with fortified soymilk, sesame seeds, almonds, and red and white beans (bioavailability of 21-24%) (69-71). Figs and soyfoods such as cooked soybeans, soynuts and tempeh provide additional calcium. Calcium-fortified foods include fruit juices, tomato juice, and breakfast cereals. Thus various food groups contribute dietary calcium (72,73). Oxalates present in some foods can greatly reduce calcium absorption, so vegetables that are very high in these compounds, such as spinach, beet greens and Swiss chard are not good sources of usable calcium despite their high calcium content. Phytate may also inhibit calcium absorption. However, some foods with high contents of both phytate and oxalate, such as soyfoods, still provide well-absorbed calcium (71). Factors that enhance calcium absorption include adequate vitamin D and protein.

Calcium intakes of lacto-vegetarians are comparable to or higher than those of non-vegetarians, (74,75) whereas intakes of vegans tend to be lower than both groups and often below recommended intakes (27,31,71,75). Diets high in sulfur-containing amino acids may increase losses of calcium from bone. Foods with a relatively high ratio of sulfur-containing amino acids to protein include eggs, meat, fish, poultry, dairy products, nuts, and many grains. There is some evidence that the impact of sulfur-containing amino acids is only important with low calcium intakes. Excessive sodium intake may also promote calcium losses. In addition, some studies show that the ratio of dietary calcium to protein is more predictive of bone health than calcium intake alone. Typically, this ratio is high in lacto-ovo-vegetarian diets and favours bone health while vegans have a calcium to protein ratio that is similar to or lower than that of non-vegetarians (71,76).

All vegetarians should meet the recommended intakes for calcium, established for their age group by the Institute of Medicine (77). This can be accomplished, in non-pregnant, non-lactating adults, by consuming at least eight servings per day of foods that provide 10-15% of the Adequate Intake (AI) for calcium, as indicated in the Vegetarian Food Guide

Pyramid and Vegetarian Food Guide Rainbow (73). Adjustments for other stages of the life cycle are available (73). Many vegans may find that it is easier to meet needs if fortified foods or supplements are included (69-71,78).

Vitamin D

Vitamin D status depends on sunlight exposure and intake of vitamin D fortified foods or supplements. Sun exposure to the face, hands, and forearms for five to 15 minutes per day during the summer at the 42nd latitude (Boston) is believed to provide sufficient amounts of vitamin D for light-skinned people (79). Those with dark skin require longer exposure (79). Sun exposure may be inadequate for those living in Canada and at northern latitudes in the United States (especially in winter months), for those in smoggy regions and for those whose sun exposure is limited. Furthermore, infants, children and older adults synthesize vitamin D less efficiently (77,79,80). Sunscreen can interfere with vitamin D synthesis, though reports are inconsistent and may depend on amount of sunscreen applied (79,81,82). Low vitamin D levels and reduced bone mass have been observed in some vegan populations at northern latitudes who did not use supplements or fortified foods, particularly children following macrobiotic diets and adult Asian vegetarians (29,83-85).

Foods that are fortified with vitamin D include cow's milk, some brands of soymilk and rice milk, as well as some breakfast cereals and margarines (See Table 1). Vitamin D3 (cholecalciferol) is of animal origin, whereas vitamin D2 (ergocalciferol) is a form acceptable to vegans. Vitamin D2 may be less bioavailable than vitamin D3, which could raise the requirements of vegetarians who depend on D2 supplements to meet vitamin D needs (86). If sun exposure and intake of fortified foods are insufficient, vitamin D supplements are recommended.

Riboflavin

Some studies have shown vegans to have lower intakes of riboflavin, compared with non-vegetarians; however clinical riboflavin deficiency has not been observed (27,29,31). In addition to foods shown in Table 1, foods that provide about 1 mg of riboflavin per serving are asparagus, bananas, beans, broccoli, figs, kale, lentils, peas, seeds, sesame tahini, sweet potatoes, tofu, tempeh, wheat germ, and enriched bread (87).

Vitamin B-12

Sources of vitamin B-12 that are not derived from animals include B-12 fortified foods (such as some brands of soymilk, breakfast cereals, and nutritional yeast) or supplements (see Table 1). Unless fortified, no plant food contains significant amounts of active vitamin B-12. Foods such as sea vegetables and spirulina may contain vitamin B-12 analogs; neither these nor fermented soy products can be counted on as reliable sources of active vitamin B-12 (29,88). Lacto-ovo-vegetarians can get adequate vitamin B-12 from dairy foods and eggs if these foods are consumed regularly.

Vegetarian diets are typically high in folic acid, which can mask the hematological symptoms of vitamin B-12 deficiency.

Therefore, some cases of deficiency may not be detected until after the onset of neurological symptoms (89). If there are concerns about vitamin B-12 status, serum homocysteine, methylmalonic acid, and holotranscobalamin II should be measured (90).

A regular source of vitamin B-12 is crucial for pregnant and lactating women, and for breastfed infants if the mother's diet is not supplemented. Infants born to vegan mothers whose diets lack reliable sources of this vitamin are at especially high risk of deficiency. Maternal vitamin B-12 intake and absorption during pregnancy appear to have a more important influence on vitamin B-12 status of the infant than do maternal vitamin B-12 stores (91).

Because 10-30% of those over the age of 50, regardless of the type of diet they follow, lose their ability to digest the protein-bound form of the vitamin that is present in eggs, dairy and other animal products, all people over the age of 50 should use vitamin B-12 supplements or fortified foods (92).

Studies indicate that some vegans and other vegetarians do not regularly consume reliable sources of vitamin B-12, and that this is reflected in less than adequate vitamin B-12 status (27,29,88,89,93-95). It is essential that all vegetarians use a supplement, fortified food, dairy products, or eggs to meet recommended intakes of vitamin B-12 (See Table 1).

Absorption is most efficient when small amounts of vitamin B-12 are consumed at frequent intervals. This could be achieved through use of fortified foods. When less than 5 µg of crystalline vitamin B-12 is consumed at one time, approximately 60% is absorbed; whereas ≤1% of a dose of 500 µg or higher of vitamin B-12 is absorbed (92).

Vitamin A/beta-carotene

Since preformed vitamin A is found only in animal foods, vegans get all of their vitamin A from conversion of dietary carotenoids, particularly beta-carotene. Research suggests that absorption of beta-carotene from plant foods is less efficient than previously believed (44,96). This suggests that vegans intake of vitamin A is about half of what previous studies have suggested and intake by lacto-ovo-vegetarians may be 25% lower than previously shown. Despite this, vegetarians have been reported to have higher serum carotenoid levels than non-vegetarians (29). Vitamin A requirements can be met with the inclusion of three servings per day of deeply yellow or orange vegetables, leafy green vegetables, or fruits that are rich in beta-carotene (apricots, cantaloupe, mango, pumpkin). Cooking increases beta-carotene absorption, as does the addition of small amounts of fat to meals (97). Chopping and pureeing vegetables may also increase bioavailability (98,99).

N-3 fatty acids

Whereas vegetarian diets are generally rich in n-6 fatty acids (specifically linoleic acid), these diets can be low in n-3 fatty acids, resulting in an imbalance that can inhibit production of the physiologically active long chain n-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Diets that do not include fish, eggs or generous amounts of sea vegetables generally lack direct sources of EPA and DHA. Recently, vegan sources of DHA derived from microalgae have

become available as supplements in non-gelatin capsules. Algae sources of DHA have been shown to positively affect blood levels of DHA and of EPA through retroconversion (100).

Most studies show vegetarians, and particularly vegans, to have lower blood levels of EPA and DHA than non-vegetarians (101-104). The new Dietary Reference Intakes recommend intakes of 1.6 and 1.1 grams of α -linolenic acid per day for men and women, respectively. These are designated as AIs rather than RDAs. These recommendations assume some intake of long chain n-3 fatty acids, and may not be optimal for vegetarians who consume little if any DHA and EPA (35). The Joint World Health Organization/Food Agriculture Organization (WHO/FAO) Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases (105) recommends 5-8% of calories from n-6 fatty acids and 1-2% of calories from n-3 fatty acids. Based on an energy intake of 2,000 kcal per day, this would suggest a daily intake of 2.2 to 4.4 grams of n-3 fatty acids. Those who do not receive a preformed source of EPA and DHA require increased amounts of n-3 fatty acids. The recommended ratio of n-6 to n-3 fatty acids is in the range of 2:1 to 4:1 (106-109).

It is recommended that vegetarians include good sources of α -linolenic acid in their diet (105,110). These would include foods like flaxseed and flaxseed oil (see Table 1). Those with increased requirements (e.g., pregnant and lactating women or those with diseases associated with poor essential fatty acid status), or those at risk for poor conversion (e.g., people with diabetes) may benefit from direct sources of long-chain n-3 fatty acids, such as DHA-rich microalgae (100,106,111).

Iodine

Some studies suggest that vegans who do not consume iodized salt may be at risk for iodine deficiency; this appears to be particularly true for those living in iodine-poor areas (29,112,113). Bread can be a source of iodine because some dough stabilizers contain iodine. In the United States, about 50% of the general population uses iodized salt, whereas in Canada, all table salt is fortified with iodine. Sea salt and kosher salt are generally not iodized; nor are salty seasonings such as tamari. Concern has been raised about vegetarian diets that include foods such as soybeans, cruciferous vegetables, and sweet potatoes that contain natural goitrogens. However, these foods have not been associated with thyroid insufficiency in healthy people provided iodine intake is adequate. The adult RDA for iodine is easily met by one-half teaspoon of iodized salt daily (44). Some vegetarians may have very high intakes of iodine, due to consumption of sea vegetables.

VEGETARIANISM THROUGHOUT THE LIFE CYCLE

Well-planned vegan, lacto-vegetarian, and lacto-ovo-vegetarian diets are appropriate for all stages of the life cycle, including pregnancy and lactation. Appropriately planned vegan, lacto-vegetarian, and lacto-ovo-vegetarian diets satisfy nutrient needs of infants, children, and adolescents and promote normal growth (36,114,115). Vegetarian diets in childhood and adolescence can aid in the establishment of lifelong healthy eating patterns and can offer some important nutritional advantages. Vegetarian children and adolescents have lower intakes of cholesterol, saturated fat and total fat, and higher

intakes of fruits, vegetables and fibre than non-vegetarians (2,116-118). Vegetarian children have also been reported to be leaner and to have lower serum cholesterol levels (119-121).

Infants

When vegetarian infants receive adequate amounts of breast milk or commercial infant formula and their diets contain good sources of energy and nutrients like iron, vitamin B-12 and vitamin D, growth throughout infancy is normal. Extremely restrictive diets such as fruitarian and raw foods diets have been associated with impaired growth and therefore cannot be recommended for infants and children (29).

Many vegetarian women choose to breastfeed their infants (122) and this practice should be encouraged and supported. The breast milk of vegetarian women is similar in composition to that of non-vegetarians and is nutritionally adequate. Commercial infant formulas should be used if infants are not breastfed or are weaned before one year of age. Soy formula is the only option for vegan infants who are not being breastfed.

Soymilk, rice milk, homemade formulas, cow's milk, and goat's milk should not be used to replace breast milk or commercial infant formula during the first year because these foods do not contain the proper ratio of macronutrients, nor do they have appropriate micronutrient levels for the young infant.

Guidelines for the introduction of solid foods are the same for vegetarian and non-vegetarian infants (115). When it is time for protein-rich foods to be introduced, vegetarian infants can have mashed or pureed tofu, legumes (pureed and strained if necessary), soy or dairy yogurt, cooked egg yolks, and cottage cheese. Later, foods such as cubes of tofu, cheese or soy cheese, and bite-size pieces of soy burger can be started. Commercial, full-fat, fortified soymilk or cow's milk can be used as a primary beverage starting at age one year or older for a child who is growing normally and is eating a variety of foods (115). Foods that are rich in energy and nutrients like legume spreads, tofu, and mashed avocado should be used when the infant is being weaned. Dietary fat should not be restricted in children younger than two years.

Breastfed infants whose mothers do not regularly consume dairy products, foods fortified with vitamin B-12, or B-12 supplements will need vitamin B-12 supplements (115). Guidelines for the use of iron and vitamin D supplements in vegetarian infants do not differ from guidelines for non-vegetarian infants. Zinc supplements are not routinely recommended for vegetarian infants since zinc deficiency is rarely seen (123). Zinc intake should be individually assessed and zinc supplements or zinc-fortified foods used during the time when complementary foods are being introduced if the diet is low in zinc or mainly consists of foods with low zinc bioavailability (124,125).

Children

Lacto-ovo-vegetarian children exhibit growth similar to that of their non-vegetarian peers (114,119,126). Little information about the growth of nonmacrobiotic vegan children is available, although findings suggest that children tend to be slightly smaller but within the normal ranges of the standards for weight and height (114,122). Poor growth in children has been seen primarily in those on very restricted diets (127).

Frequent meals and snacks and the use of some refined foods (such as fortified breakfast cereals, breads, and pasta) and foods higher in unsaturated fat can help vegetarian children meet energy and nutrient needs. Average protein intake of vegetarian children (lacto-ovo, vegan, and macrobiotic) generally meets or exceeds recommendations, although vegetarian children may consume less protein than non-vegetarian children (116,128). Vegan children may have protein needs that are slightly higher than those of non-vegan children due to differences in protein digestibility and amino acid composition of plant food proteins (36,129), but these protein needs are generally met when diets contain adequate energy and a variety of plant foods (35). Good sources of calcium, iron, and zinc should be emphasized for vegetarian children along with dietary practices that enhance absorption of zinc and iron from plant foods. A reliable source of vitamin B-12 is important for vegan children. If there is concern about vitamin D synthesis due to limited sunlight exposure, skin tone, season, or sunscreen use, vitamin D supplements or fortified foods should be used. Table 1 provides information about food sources of nutrients. Food guides for vegetarian children under four years (36,130) and for older children (73) have been published elsewhere.

Adolescents

There are limited data available on the growth of vegetarian adolescents, although studies suggest there is little difference between vegetarians and non-vegetarians (131). In the West, vegetarian girls tend to reach menarche at a slightly later age than western non-vegetarians (132,133), although not all research supports this finding (134,135). If slightly later menarche does occur, it may offer health advantages including lower risk of developing breast cancer and obesity (136,137). Vegetarian diets appear to offer some nutritional advantages for adolescents. Vegetarian adolescents are reported to consume more fibre, iron, folate, vitamin A, and vitamin C than non-vegetarians (2,60). Vegetarian adolescents also consume more fruits and vegetables, and fewer sweets, fast foods, and salty snacks compared to non-vegetarian adolescents (2,118). Key nutrients for adolescent vegetarians include calcium, vitamin D, iron, zinc, and vitamin B-12.

Vegetarian diets are somewhat more common among adolescents with eating disorders than in the general adolescent population; therefore, dietetics professionals should be aware of young clients who greatly limit food choices and who exhibit symptoms of eating disorders (138,139). However, recent data suggest that adopting a vegetarian diet does not lead to eating disorders, rather vegetarian diets may be selected to camouflage an existing eating disorder (27,140,141). With guidance in meal planning, vegetarian diets are appropriate and healthful choices for adolescents.

Pregnant and lactating women

Lacto-ovo-vegetarian and vegan diets can meet the nutrient and energy needs of pregnant women. Infants of vegetarian mothers generally have birth weights that are similar to those of infants born to non-vegetarians and to birth weight norms (122,142,143). Diets of pregnant and lactating vegans should contain reliable sources of vitamin B-12 daily. If there is concern

about vitamin D synthesis due to limited sunlight exposure, skin tone, season, or sunscreen use, pregnant and lactating women should use vitamin D supplements or fortified foods. Iron supplements may be needed to prevent or treat iron-deficiency anemia, which is commonly seen in pregnancy. Women capable of becoming pregnant and women in the periconceptional period are advised to consume 400 µg of folate daily from supplements, fortified foods, or both in addition to consuming food folate from a varied diet (92).

Infants of vegetarian mothers have been reported to have lower cord and plasma DHA than do infants of non-vegetarians, although the functional significance of this is not known (104,143). Breast milk DHA levels in vegan and lacto-ovo-vegetarian women appear to be lower than levels in non-vegetarians (144). Because DHA seems to play a role in the development of the brain and the eye and because a dietary supply of DHA may be important for the fetus and newborn, pregnant and lactating vegans and vegetarians (unless eggs are eaten regularly) should include sources of the DHA precursor linolenic acid in their diet (ground flaxseed, flaxseed oil, canola oil, soybean oil) or use a vegetarian DHA supplement (from microalgae). Foods containing linoleic acid (corn, safflower, and sunflower oil) and *trans*-fatty acids (stick margarine, foods with hydrogenated fats) should be limited since these fatty acids can inhibit DHA production from linolenic acid (145).

Older adults

Studies indicate that most older vegetarians have dietary intakes that are similar to non-vegetarians (146,147). With aging, energy needs decrease but recommendations for several nutrients including calcium, vitamin D, vitamin B6, and possibly protein are higher. Sunlight exposure is often limited and vitamin D synthesis is decreased in older adults so that dietary or supplemental sources of vitamin D are especially important.

Older adults may have difficulty with vitamin B-12 absorption from food, so vitamin B-12-fortified foods or supplements should be used, since the vitamin B-12 in fortified foods and supplements is usually well-absorbed (92). Protein requirements for older adults are controversial. The current DRIs do not recommend additional protein for older adults (35). A meta-analysis of nitrogen balance studies concluded that there is not enough evidence to recommend different protein intakes for older adults but pointed out that the data are limited and contradictory (34). Others have concluded that protein requirements of older adults may be around 1 to 1.25 g/kg body weight (148,149). Older adults can easily meet protein needs on a vegetarian diet if a variety of protein-rich plant foods, including legumes and soy products, is eaten daily.

Vegetarian diets, which are high in fibre, may be beneficial for older adults with constipation. Older vegetarians may benefit from nutritional counselling on foods that are easy to chew, require minimal preparation, or are appropriate for therapeutic diets.

Athletes

Vegetarian diets can also meet the needs of competitive athletes. Nutrition recommendations for vegetarian athletes should be formulated with consideration of the effects of both vegetarianism and exercise. The position of the American

Dietetic Association and Dietitians of Canada on nutrition and athletic performance (39) provides appropriate dietary guidance for athletes, although some modification may be needed to address vegetarians' needs. Protein recommendations for endurance athletes are 1.2 to 1.4 g/kg body weight while resistance and strength-trained athletes may need as much as 1.6 to 1.7 g/kg body weight (39). Not all groups support an increased protein need for athletes (35). Vegetarian diets that meet energy needs and contain a variety of plant-based protein foods, such as soy products, other legumes, grains, nuts, and seeds, can provide adequate protein without the use of special foods or supplements (150). For adolescent athletes, special attention should be given to meeting energy, protein, calcium, and iron needs. Amenorrhea may be more common among vegetarian than non-vegetarian athletes, although not all research supports this finding (151,152). Female vegetarian athletes may benefit from diets that include adequate energy, higher levels of fat, and generous amounts of calcium and iron.

VEGETARIAN DIETS AND CHRONIC DISEASE

Obesity

Among Seventh-day Adventists (SDA), 40% of whom follow a meatless diet, vegetarian eating patterns have been associated with lower body mass index (BMI). In the Adventist Health Study, which compared vegetarians and non-vegetarians within the Adventist population, BMI increased as the frequency of meat consumption increased in both men and women (4). In the Oxford Vegetarian Study, BMI values were higher in non-vegetarians compared to vegetarians in all age groups and for both men and women (112).

In a study of 4,000 men and women in England comparing the relationship between meat consumption and obesity among meat eaters, fish eaters, lacto-ovo-vegetarians, and vegans, mean BMI was highest in the meat eaters and lowest in the vegans (153). BMI was lowest in those lacto-ovo-vegetarians and vegans who had adhered to their diet for five years or longer.

Factors that may help to explain the lower BMI among vegetarians include differences in macronutrient content (lower protein, fat, and animal fat intake), higher fibre consumption, decreased alcohol intake, and greater consumption of vegetables.

Cardiovascular disease

An analysis of five prospective studies involving more than 76,000 subjects showed that death from ischemic heart disease was 31% lower among vegetarian men compared to non-vegetarian men and 20% lower among vegetarian women compared to non-vegetarian women (154). Death rates were also lower for vegetarian men and women compared to semi-vegetarians, those who ate fish only or ate meat less than once per week. Among SDA, vegetarian men had a 37% reduction in risk of developing ischemic heart disease compared to non-vegetarian men (4). In the only study to include vegan subjects, risk for developing heart disease was even lower among SDA vegan men than in the SDA lacto-ovo-vegetarians (155).

The lower rates of heart disease among vegetarians are explained in part by their lower blood cholesterol levels. A review of nine studies found that, in comparison to non-vegetarians, lacto-ovo-vegetarians and vegans had mean blood cholesterol levels that were 14% and 35% lower respectively

(156). Although the lower average BMI of vegetarians may help to explain this, Sacks et al. found that, even when vegetarian subjects were heavier than non-vegetarian subjects, the vegetarians had markedly lower plasma lipoprotein values (157) and Thorogood et al. found that differences in plasma lipids in vegetarians, vegans, and meat-eaters persisted even following adjustment for BMI (158). Some, but not all studies have shown lower high density lipoprotein (HDL) levels in vegetarian subjects (29). Lower HDL levels may be due to the type or amount of dietary fat or to lower alcohol intake. This may help to explain the smaller differences in heart disease rates between vegetarian and non-vegetarian women since HDL may be a more important risk factor than LDL levels for women (159). Average triglyceride levels tend to be similar in vegetarians and non-vegetarians.

A number of factors in vegetarian diets may affect cholesterol levels. Although studies show that most vegetarians do not typically consume low fat diets, saturated fat intake is considerably lower among vegetarians than non-vegetarians and vegans have a lower ratio of saturated to unsaturated fat in their diets (29). Vegetarians also consume less cholesterol than non-vegetarians, although the range of intake varies considerably across studies. Vegan diets are free of cholesterol.

Vegetarians consume between 50%-100% more fibre than non-vegetarians and vegans have higher intakes than lacto-ovo-vegetarians (29). Soluble fibre may lower risk for cardiovascular disease by reducing blood cholesterol levels (160). Limited research suggests that animal protein is directly associated with higher serum cholesterol levels even when other dietary factors are controlled (161). Lacto-ovo-vegetarians consume less animal protein than non-vegetarians and vegans consume no animal protein. Research shows that consumption of at least 25 g per day of soy protein, either in place of animal protein or in addition to the usual diet, reduces cholesterol levels in people with hypercholesterolemia (162). Soy protein may also raise HDL levels (162). Vegetarians are likely to consume more soy protein than the general population.

Other factors in vegetarian diets may impact cardiovascular disease risk independent of effects on cholesterol levels. Vegetarians have higher intakes of the vitamin antioxidants vitamins C and E, which may reduce oxidation of LDL-cholesterol. Isoflavones, which are phytoestrogens found in soyfoods, may also have antioxidant properties (163) as well as enhancing endothelial function and arterial compliance (164). Although there is limited information available about intake of specific phytochemicals among population groups, vegetarians appear to consume more phytochemicals than non-vegetarians because a greater percentage of their energy comes from plant foods. Some phytochemicals may affect plaque formation through effects on signal transduction and cell proliferation (165) and may exert anti-inflammatory effects (166). Research from Taiwan found that vegetarians had significantly better vasodilation responses, which correlated directly with years on a vegetarian diet, suggesting a direct beneficial effect of vegetarian diet on vascular endothelial function (167).

Not all aspects of vegetarian diets are associated with reduced risk for heart disease. Some (89,101,168-171) but not all (62,172) studies have found higher serum homocysteine levels in vegetarians compared to non-vegetarians. Homocysteine

is believed to be an independent risk factor for heart disease. Inadequate intake of vitamin B-12 may be the explanation. Vitamin B-12 injections lowered homocysteine levels in vegetarians, many of whom had low B-12 levels and high serum homocysteine (173). In addition, low intakes of n-3 fatty acids and a high ratio of n-6 to n-3 fatty acids in the diet may raise risk of heart disease among some vegetarians (173).

There are only limited data on the role of vegetarian diets as intervention for heart disease. Vegetarian diets used in these studies have usually been very low in fat. Because these diets have been used along with other lifestyle changes and they have produced weight loss, it has not been possible to ascertain any direct effect of adoption of vegetarian diet on risk factors for heart disease or mortality. Vegetarian diets can be planned to conform to standard recommendations for the treatment of hypercholesterolemia.

Hypertension

Many studies show that vegetarians have both lower systolic and diastolic pressures with differences between vegetarians and non-vegetarians generally falling between 5 and 10 mm/Hg (29). In the Hypertension Detection and Follow-Up Program, blood pressure reduction of just 4 mm/Hg caused marked reduction in mortality from all causes (174).

In addition to having lower blood pressures in general, vegetarians have markedly lower rates of hypertension than meat eaters (175,176). In one study, 42% of non-vegetarians had hypertension (defined as 140/90 mm/Hg) compared with only 13% of vegetarians. Even semi-vegetarians are 50% more likely to have hypertension than vegetarians (4). Even when body weights were similar between subjects, vegetarians had lower blood pressures. Placing non-vegetarian subjects on a vegetarian diet led to reduced blood pressure in normotensive (177), and hypertensive subjects (178).

A number of studies have controlled for various factors that might help to explain the lower blood pressures of vegetarians and the hypotensive effects of changing to a vegetarian diet. The lower blood pressures do not appear to be due to lower BMI (175), exercise habits (179), absence of meat (180), milk protein (181), fat content of diet (182), fibre (183), or differences in potassium, magnesium, or calcium intakes (184). Because sodium intake of vegetarians is comparable or only modestly lower than that of non-vegetarians, sodium does not explain the differences either. Suggested explanations include a difference in blood glucose-insulin response due to a lower glycemic index of vegetarian diets (185) or a collective effect of beneficial compounds from plant foods (186).

Diabetes

Vegetarian diets can meet guidelines for the treatment of diabetes (187) and some research suggests that diets that are more plant-based reduce risk for type 2 diabetes. Rates of self-reported diabetes among Seventh-day Adventists (SDA) were less than half those of the general population and among SDA, vegetarians had lower rates of diabetes than non-vegetarians (188). In the Adventist Health Study, age-adjusted risk for developing diabetes for vegetarian, semivegetarian, and non-vegetarian men was 1.00, 1.35, and 1.97 and for women it was 1.00, 1.08, and 1.93 (4). Among the possible

explanations for a protective effect of vegetarian diet are the lower BMI of vegetarians and higher fibre intake, both of which improve insulin sensitivity. However, among men in the Adventist Health Study, risk for diabetes was still 80% higher in non-vegetarian men after adjustment for weight. In men, meat consumption was directly associated with increased risk of diabetes. Among women, risk increased only when meat consumption exceeded five servings per week (188).

Cancer

Vegetarians have an overall lower cancer rate compared to the general population but it is not clear to what extent this is due to diet. When non-dietary cancer risk factors are controlled for, differences in overall cancer rates between vegetarians and non-vegetarians are greatly reduced although marked differences remain in rates of certain cancers. An analysis from the Adventist Health Study that controlled for age, sex, and smoking found no differences between vegetarians and non-vegetarians for lung, breast, uterine, or stomach cancer but did find that non-vegetarians had a 54% increased risk for prostate cancer and an 88% increased risk for colorectal cancer (4). Other research has shown lower rates of colon cell proliferation in vegetarians compared to non-vegetarians (189) and lower levels of serum insulin-like growth factor-I, thought to be involved in the etiology of several cancers in vegans compared to both non-vegetarians and lacto-ovo-vegetarians (190). Both red and white meat have been independently linked to increased risk for colon cancer (4). Observational studies have found an association between high intake of dairy foods and calcium with increased risk for prostate cancer (191-193) although not all studies support this finding (194). A pooled analysis of 8 observational studies found no link between meat or dairy consumption and breast cancer (195).

Research suggests that a number of factors in vegetarian diets may impact cancer risk. Vegetarian diets come closer to matching the dietary guidelines issued by the National Cancer Institute than do non-vegetarian diets, particularly in regard to fat and fibre intakes (196). Although data on fruit and vegetable intake of vegetarians are limited, a recent study found that intake was considerably higher among vegans compared to non-vegetarians (62). High lifetime exposure to estrogen has been linked to increased breast cancer risk. Some research shows that vegetarians have lower serum and urinary estrogen levels (197). There is also some evidence that vegetarian girls begin menstruation at a later age, which may reduce cancer risk because of lower lifetime estrogen exposure (132,133). High fibre intake is believed to protect against colon cancer, although not all research supports this (198,199). The environment of the colon of vegetarians is strikingly different from that of non-vegetarians. Vegetarians have a lower concentration of potentially carcinogenic bile acids (200) and fewer intestinal bacteria that convert the primary bile acids into carcinogenic secondary bile acids (201). More frequent elimination and the levels of certain enzymes in the colon enhance elimination of potential colon carcinogens (200,202). Most research shows that vegetarians have lower levels of fecal mutagens (203).

Vegetarians do not consume heme iron, which has been shown to lead to the formation of highly cytotoxic factors in the colon increasing colon cancer risk (204). Finally, vegetarians

most likely have higher intakes of phytochemicals, many of which have anti-cancer activity. Isoflavones in soyfoods have been shown to have anticancer effects particularly in regard to breast and prostate cancer, although this is not supported by all research (205,206).

Osteoporosis

Osteoporosis is a complex disease affected by a variety of lifestyle, dietary, and genetic factors. Although some data indicate that osteoporosis is less common in developing countries with a mostly plant-based diet, these studies have relied on hip fracture data, which has been found to be unreliable for comparing bone health across cultures. There is little evidence to suggest that bone mineral density differs between western non-vegetarians and lacto-ovo-vegetarians.

A number of studies have shown that high protein intake, from animal foods in particular, causes increased excretion of calcium and raises calcium needs (207-209).

The effect is believed to be due to the increased acid load from metabolism of sulfur-containing amino acids (SAA). However, grains are also high in these amino acids and some research shows that SAA intake was similar between non-vegetarians and vegetarians (210). Despite this, there is some evidence that post-menopausal women with diets high in animal protein and low in plant protein had a high rate of bone loss and a greatly increased risk of hip fracture (211). While excessive protein intake may compromise bone health, there is evidence that low protein intakes could raise risk for poorer bone health (212). Although there are very little reliable data on bone health of vegans, some studies suggest that bone density is lower among vegans compared to non-vegetarians (213-215). Vegan women, like other women, may have low calcium intakes despite the availability of nondairy sources of well-absorbed calcium. Some vegan women may also have protein intakes that are marginal and vitamin D status has been shown to be compromised in some vegans (216-218). The lower serum estrogen levels of vegetarians may be a risk factor for osteoporosis. In contrast, short-term clinical studies suggest that soy protein rich in isoflavones decreases spinal bone loss in post-menopausal women (219). Higher intake of potassium and vitamin K among vegetarians may also help to protect bone health. However, the data suggest that a vegetarian diet does not necessarily protect against osteoporosis despite lower animal protein content.

Renal disease

High intake of dietary protein may worsen existing kidney disease or increase risk for those who are susceptible to this disease because protein intake is associated with a higher glomerular filtration rate (GFR) (220). The GFR of healthy vegetarians is lower than that of non-vegetarians and even lower in vegans (221). The type of protein consumed may also have an effect with plant foods having a more beneficial effect on GFR than animal protein (222, 223). GFR was 16% higher in healthy subjects after eating a meal containing animal protein compared to a meal with soy protein (222). Because the pathology of renal disease is similar to that of atherosclerosis, the lower serum cholesterol levels and reduced cholesterol oxidation resulting from a vegetarian diet may be beneficial for those with kidney disease.

Dementia

Although rates of dementia differ markedly throughout the world, differences in diagnostic criteria make cross-cultural comparisons difficult. In the United States, among Seventh-day Adventists (SDA), those who ate meat were more than twice as likely to develop dementia (224). Those who had eaten meat for many years were more than three times as likely to develop signs of dementia. Diets high in antioxidants have been found to protect cognitive function (225-227). The lower blood pressure of vegetarians may also be protective. There is also some evidence that lower blood cholesterol protects against dementia (228). Higher homocysteine levels are linked to increased risk of dementia and this may present one risk factor for vegetarians who do not get adequate vitamin B-12 (229-232). Although one observational study found an increased rate of dementia among Japanese American men who ate tofu regularly (233), the study had a number of methodological limitations and other research has not supported these findings (234).

Other health effects of vegetarian diets

Diverticular Disease. Gear et al. found that both male and female vegetarians aged 45 to 59 years were 50% as likely to have diverticulitis compared to non-vegetarians (235). Although fibre is believed to be the most important reason for this difference, other factors may have an effect as well. High-fat diets, independent of fibre intake, have been associated with increased risk of diverticulitis (236). Meat intake may also increase risk (236). Older research suggests that meat consumption may promote growth of bacteria that produce a toxic metabolite that weakens the wall of the colon (237).

Gallstones. In a study of 800 women aged 40 to 69 years, non-vegetarians were more than twice as likely as vegetarians to suffer from gallstones (238). The relationship held even after controlling for the three known risk factors for gallstones – obesity, gender, and aging.

Rheumatoid arthritis. Rheumatoid arthritis (RA), believed to be an autoimmune disease, involves inflammation of the joints. Several studies from one group of researchers in Finland suggest that fasting, followed by vegan diet, may be useful in treatment of RA (239,240).

Although data are very limited and more follow-up is needed before conclusions can be drawn, some studies suggest that a mostly raw foods vegan diet reduces symptoms of fibromyalgia (241) and a vegetarian diet may reduce symptoms of topical dermatitis (242).

PROGRAMS AND AUDIENCES IMPACTED

Special supplemental nutrition program for women, infants and children

In the United States, the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) is a federal grant program that serves pregnant, postpartum, and breastfeeding women, infants, and children up to five years who are documented as being at nutritional risk and with family income below state standards. This program provides checks or coupons to purchase some foods suitable for vegetarians including infant formula, iron-fortified infant cereal, vitamin C-rich fruit or vegetable juice, carrots, cow's milk, cheese, eggs, iron-fortified

ready-to-eat cereal, dried beans or peas, and peanut butter. Individual state agencies are allowed to submit a plan to USDA's Food and Nutrition Service for substitution of foods to allow for different cultural eating patterns provided the proposed substitute food is nutritionally equivalent or superior to the food it replaces, is widely available, and does not cost more than the food it is to replace (243). This provision could possibly allow more foods suitable for vegans to be purchased.

Canada Prenatal Nutrition Program (CPNP), federally funded by Health Canada, and perinatal community programs provide vouchers, coupons or groceries to those who meet the income and nutritional risk criteria for the program. Vouchers can be used for some foods acceptable to vegetarians including milk, juice, cheese, eggs, fortified soymilk, and other foods (244).

Child nutrition programs

In the United States, the National School Lunch Program (NSLP) allows non-meat protein products including certain soy products, cheese, eggs, cooked dried beans or peas, yogurt, peanut butter, other nut or seed butters, peanuts, tree nuts, and seeds to be used (245,246). USDA information for school foodservice personnel includes several vegetarian and vegan quantity recipes (247). Few public schools regularly feature vegetarian menu items. School lunches are not adequate for vegans even when some vegan options are available, since soymilk can only be served as a part of school lunch in cases of documented lactose intolerance.

In Canada, school lunch, breakfast and snack programs, food selection standards, and provision for vegetarian meals vary from one region to another. Nationally, the Canadian Living Foundation's Breakfast for Learning program is developing Best Practice Program Standards for breakfast, snack and lunch programs. Vegetarian meals based on Canada's Food Guide to Healthy Eating fit within this framework (248).

Feeding programs for the elderly

The federal Elderly Nutrition Program (ENP) distributes funds to states, territories, and tribal organizations for a national network of programs that provide congregate and home delivered meals (often known as Meals on Wheels) for older Americans. Meals served under this program must provide at least one-third of the RDAs (249). Meals are often provided by local Meals on Wheels agencies. A four-week set of vegetarian menus has been developed for use by the National Meals on Wheels Foundation (250,251).

Corrections facilities

Court rulings in the United States and Canada have granted prison inmates the right to have vegetarian meals for religious and medical reasons (and in Canada, by choice, as well) (252,253). Federal institutions and those for many states and provinces provide vegetarian options for meals. The Canadian federal court has ruled that prison inmates who are opposed to eating meat have a constitutional right to be served vegetarian meals. The Freedom of Conscience provisions in the Charter of Rights allow prisoners to demand vegetarian fare for moral reasons, just as other inmates may request special meals on religious or medical grounds. (252).

Table 2
Useful Web sites

General Vegetarian Nutrition:

Food and Nutrition Information Center, USDA
<http://www.nal.usda.gov/fnic/etext/000058.html>
<http://www.nal.usda.gov/fnic/pubs/bibs/gen/vegetarian.htm>

Loma Linda University Vegetarian Nutrition & Health Letter
<http://www.llu.edu/llu/vegetarian/vegnews.htm>

Seventh-day Adventist Dietetic Association
<http://www.sdada.org/facts&fiction.htm>

Vegan Outreach
<http://www.veganoutreach.org/whyvegan/health.html>
<http://www.veganoutreach.org/health/stayinghealthy.html>

The Vegan Society (vitamin B-12)
www.vegansociety.com/html/info/b12sheet.htm

Vegetarian Nutrition Dietetic Practice Group
<http://www.vegetariannutrition.net>

Vegetarian Resource Group
<http://www.vrg.org>

The Vegetarian Society of the United Kingdom
<http://www.vegsoc.org/health>

VegRD
<http://vegrd.vegan.com>

Travel:
Happy Cow's Global Guide to Vegetarian Restaurants
www.happycow.net

VegDining.com
www.vegdining.com/Home.cfm

Vegetarian Resource Group
www.vrg.org/travel

Quantity Food Preparation:
Vegetarian Resource Group
<http://www.vrg.org/fsupdate>

Military/armed forces

The US Army's Combat Feeding Program, which oversees all food regulations, provides a choice of vegetarian menus (254). Canadian Forces Food Services offers one or more vegetarian options at every meal (255). An estimated 10- 15% of Canadian Forces members choose vegetarian meals for combat rations (individual meal packs) (256).

Other institutions and quantity food service organizations

Other institutions, including colleges, universities, hospitals, restaurants, and publicly funded museums and parks, offer varying amounts and types of vegetarian selections. Resources are available for vegetarian quantity food preparation (Table 2). As interest in vegetarianism grows, and because of the nutritional and health benefits of choosing a vegetarian diet, increased provision of vegetarian meals on a daily basis should be encouraged.

ROLE OF DIETETICS PROFESSIONALS

Vegetarian clients may seek nutrition counselling services for a specific clinical condition or for assistance in planning healthful vegetarian diets. They may sometimes be referred because of problems related to poor diet choices. Dietetics professionals have an important role in supporting clients who express an interest in adopting vegetarian diets or who already eat a vegetarian diet. It is important for dietetics professionals to support any client who chooses this style of eating and to be able to give current accurate information about vegetarian nutrition. Information should be individualized depending on type of vegetarian diet, age of the client, food preparation skills, and activity level. It is important to listen to the client's own description of his or her diet to ascertain which foods can play a role in meal planning. Table 2 provides a listing of Web resources on vegetarianism. Table 3 includes meal planning tips. Qualified dietetics professionals can help vegetarian clients in the following ways:

- Provide information about meeting requirements for vitamin B-12, calcium, vitamin D, zinc, iron, and n-3 fatty acids

Table 3
Meal planning

A variety of menu planning approaches can provide adequate nutrition for vegetarians. The Vegetarian Food Guide Pyramid and Vegetarian Food Guide Rainbow (73) suggest one approach. In addition, the following guidelines can help vegetarians plan healthful diets:

- Choose a variety of foods including whole grains, vegetables, fruits, legumes, nuts, seeds, and if desired, dairy products, and eggs.
- Choose whole, unrefined foods often and minimize the intake of highly sweetened, fatty and heavily refined foods.
- Choose a variety of fruits and vegetables.
- If animal foods such as dairy products and eggs are used, choose lower-fat dairy products and use both eggs and dairy products in moderation.
- Use a regular source of vitamin B-12 and, if sunlight exposure is limited, of vitamin D.

since poorly planned vegetarian diets may sometimes fall short of these nutrients.

- Give specific guidelines for planning balanced lacto-ovo-vegetarian or vegan meals for all stages of the life cycle.
- Adapt guidelines for planning balanced lacto-ovo-vegetarian or vegan meals for clients with special dietary needs due to allergies or chronic disease or other restrictions.
- Be familiar with vegetarian options at local restaurants.
- Provide ideas for planning optimal vegetarian meals while travelling.
- Instruct clients about the preparation and use of foods that frequently are part of vegetarian diets. The growing selection of products aimed at vegetarians may make it impossible to be knowledgeable about all such products. However, practitioners working with vegetarian clients should have a basic knowledge of preparation, use, and nutrient content

of a variety of grains, beans, soy products, meat analogs and fortified foods.

- Be familiar with local sources for purchase of vegetarian foods. In some communities, mail order sources may be necessary.
- Work with family members, particularly the parents of vegetarian children, to help provide the best possible environment for meeting nutrient needs on a vegetarian diet.
- If a practitioner is unfamiliar with vegetarian nutrition, he/she should assist the individual in finding someone who is qualified to advise the client or should direct the client to reliable resources.

CONCLUSIONS

Appropriately planned vegetarian diets have been shown to be healthful, nutritionally adequate, and to be beneficial in the prevention and treatment of certain diseases. Vegetarian diets are appropriate for all stages of the life cycle. There are many reasons for the rising interest in vegetarianism. The number of vegetarians in the United States and Canada is expected to increase over the next decade. Dietetics professionals can assist vegetarian clients by providing current, accurate information about vegetarian nutrition, foods, and resources.

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- DC/ADA Position adopted by the House of Delegates on October 18, 1987, and reaffirmed on September 12, 1992, September 6, 1996 and June 22, 2000. This position was developed collaboratively between the American Dietetic Association and Dietitians of Canada. This position will be in effect until December 31, 2007. DC/ADA authorize republication of the position statement/support paper, in its entirety, provided full and proper credit is given. Requests to use portions of the position must be directed to ADA Headquarters at 800/877-1600, ext 4835, or ppapers@eatright.org
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