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Review

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Plant-based nutrition for healthcare professionals: implementing diet as a primary modality in the prevention and treatment of chronic disease

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Abstract

Cardiovascular disease remains the world's leading cause of death. Yet, we have known for decades that the vast majority of atherosclerosis and its subsequent morbidity and mortality are influenced predominantly by diet. This paper will describe a health-promoting whole food, plant-based diet; delineate macro- and micro-nutrition, emphasizing specific geriatric concerns; and offer guidance to physicians and other healthcare practitioners to support patients in successfully utilizing nutrition to improve their health.

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1 Introduction

Today, many early deaths in the United States are preventable and nutrition-related. According to an analysis of risk factors over the period 1990–2010, the leading cause of early death and disability in the United States is diet.[1] The authors note: "The most important dietary risks in the United States are diets low in fruits, low in nuts and seeds, high in sodium, high in processed meats, low in vegetables, and high in trans fats." Geoffrey Rose proposes[2] that at every office visit, there is an obligation to ask, "Why did this patient get this disease at this time?" He adds, "It is an integral part of good doctoring to ask not only, what is the diagnosis, and what is the treatment? but also, why did this happen, and could it have been prevented?" This approach relates to the sage advice of Hippocrates,[3] the "physician must not only be prepared to do what is right himself, but also to make the patient, the attendants, and the externals cooperate.[3]"

Substantive dietary intervention requires significant efforts by both patients and healthcare providers. For this reason, potential bias may hinder compliance or even create the appearance of conflicting advice.[4–6] When nutrition practices are discussed with patients, physicians typically spend an average of five minutes on the topic, which may not provide enough time and detail for success.[7] Unfortunately, pharmacological and procedural interventions are more common than dietary interventions. Diet is often viewed as more difficult to implement as it is an intrinsic part of culture, family, and self-identity. Recommending a diet that is widely divergent from either the patient's or attendant physician's personal choice may be likened to social discordance surrounding smoking in the 1930s through early 1950s. At that time, the majority of physicians smoked but nonetheless were increasingly responsible for beginning office visits with advice discouraging smoking.[8,9]

With accumulating scientific evidence supporting its health advantages, whole food, plant-based diets are steadily on the rise.[10] Moving from the standard "meat and potatoes" diet to one that features whole plants often requires restructuring and the development of new skills. With practice and the accumulation of nutrition knowledge and a repertoire of recipes, this lifestyle becomes progressively easier.

A whole food, plant-based diet consists of vegetables, fruits, legumes, whole grains, nuts, seeds, herbs, and spices, which can be consumed in infinite combinations (Table 1). In accordance with the United States Department of Agriculture, American Heart Association, and American Institute for Cancer Research, half of the plate should consist of vegetables and fruits in order to ensure adequate intake of fiber, potassium, magnesium, folate, iron, and vitamins A and C, nutrients that tend to be low in the standard Western diet.[11]

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Table 1. Food groups and recommended servings per day.

Food group	Recommended servings per day
Vegetables, all types including starchy vegetables	Ad libitum, with a variety of colors represented
Fruits, all types	2–4 servings (1 serving = 1 medium piece of 1/2 cup)
Whole grains (e.g., brown rice, quinoa, oats)	6–11 servings (1 serving = 1/2 cup cooked or 1 slice whole grain bread)
Legumes (beans, lentils, peas, soy foods)	2–3 servings (1 serving = 1/2 cup cooked)
Leafy green vegetables (e.g., broccoli, cabbage, lettuce)	At least 2–3 servings (1 serving = 1 cup raw or 1/2 cup cooked)
Nuts (e.g., almonds, pecans, walnuts)	1–2 ounces
Seeds (e.g., chia, flax, hemp seeds)	1–3 tablespoons
Fortified plant milks (e.g., almond, soy, rice)	Optional, 2–3 cups
Fresh herbs and spices	Optional, ad libitum

Plant-based diets are associated with lowering overall mortality and ischemic heart disease mortality;[12,13] reducing medication needs;[14–16] supporting sustainable weight management;[17–21] reducing incidence and severity of high-risk conditions, such as obesity[22] and obesity-related inflammatory markers,[23] hyperglycemia,[24,25] hypertension,[26–28] and hyperlipidemia;[29] and even reversing advanced cardiovascular disease and type 2 diabetes.[25,30,31]

These advantages are likely the result of both the consistent consumption of innate health-promoting compounds found in whole plant foods and the reduction of exposure to harmful substances found in animal products and highly processed foods. Meat (including processed, red, and white assortments), fish, dairy, and eggs contain health-damaging saturated fats, heme iron, N-glycolylneuraminic acid (Neu5Gc), carnitine, and chemical contaminants formed when flesh is cooked, such as polycyclic aromatic hydrocarbons, heterocyclic amines, and advanced glycation end products. Highly processed foods encompass a class of commercially produced items made with adulterants including oils, salts, sugars, and other food additives.[32–52] These aforementioned constituents in animal products and processed foods contribute to inflammation, oxidation, and carcinogenesis, promoting disease and, therefore, are better omitted from the diet.

Plant foods exclusively contain two critical nutrients: fiber and phytonutrients. Fiber, found in multiple varieties in all intact plant foods, proffers powerful protection of the gastrointestinal, cardiovascular, and immune systems, while phytonutrients, a vast class of thousands of compounds including glucosinolates, carotenoids, and flavonoids, work synergistically to reduce inflammation and oxidation, providing protection from disease initiation and progression.[53–60]

Interestingly, longevity, aging, and healthspan investigations provide cellular, mechanistic evidence that support dietary intervention in the prevention and treatment of cardiovascular disease.[61] A plant-based diet is a practical way of implementing dietary restriction and may positively impact a variety of metabolic pathways that are under pharmacologic investigation given their potential health benefits in humans. They include inhibition of the growth hormone (GH) and insulin-like growth factor 1 (IGF-1) axis, mammalian target of rapamycin (mTOR) pathway, and inflammation and activation of sirtuins and adenosine monophosphate kinase (AMPK).[62–67] Additionally, protein (essential amino acid) restriction, traditionally seen as a limitation of a vegetarian or vegan diet, may confer similar benefits to those seen in dietary restriction experiments in a wide range of organisms, from yeast to primates.[68–72] While reduced levels of dietary amino acids, such as methionine and leucine were once seen as limitations for plant-sourced proteins, it is now recognized as potentially beneficial.

2 Geriatric nutrition

Several issues to consider with respect to nutrition in the elderly include altered appetite, caloric, and nutrient needs as well as dentition and dexterity. Although seniors typically require fewer calories because of the natural reduction in muscle mass (sarcopenia) and decreased physical activity, these matters leave concern for malnutrition.[73–75] Although there is variance in approach depending upon current weight status (see Box 1), the goal is nutrient adequacy, while avoiding malnutrition, both under- and over-nutrition. Special nutritional needs, including increased protein needs, vitamin B12 absorption, vitamins and minerals for bone health, long-chain omega-3 fatty acids, and more will be discussed in detail below (See Table 2 for Food Sources of Notable Nutrients).

3 Meeting energy needs

Geriatric patients who struggle to consume enough calories should increase their intake of more calorically dense plant-based foods. Examples appropriate for those with poor

Box 1. Overweight and underweight.

For overweight patients, recommend shifting diet up the Food Triangle (Figure 1) to focus on higher fiber leafy greens, starchy vegetables, and legumes and to limit nuts, seeds, and avocado during weight loss period.

For underweight patients, increase nuts, seeds, avocados and eat together with lower fiber starchy vegetables and fruits (e.g., green smoothies, nut and seed butter spreads, sauces, and dressings).

Table 2. Sources of notable nutrients.

Nutrient	Food sources
Protein	Legumes (beans, lentils, peas, peanuts), nuts, seeds, soy foods (tempeh, tofu)
Omega-3 fats	Seeds (chia, flax, hemp), leafy green vegetables, microalgae, soybeans and soy foods, walnuts, wheat germ, supplement
Fiber	Vegetables, fruits (especially berries, papayas, pears, dried fruits), avocados, legumes (beans, lentils, peas), nuts, seeds, whole grains
Calcium	Low-oxalate leafy greens (bok choy, broccoli, cabbage, collard, dandelion, le, watercress), calcium-set tofu, almonds, almond butter, fortified plant milks, sesame seeds, tahini, figs, blackstrap molasses
Iodine	Sea vegetables (e.g., arame, dulse, nori, wa me), iodized salt, supplement if necessary
Iron	Legumes (beans, lentils, peas, peanuts), leafy greens, soybeans and soy foods, quinoa, potatoes, dried fruit, dark chocolate, tahini, seeds (pumpkin, sesame, sunflower), sea vegetables (dulse, nori)
Zinc	Legumes (beans, lentils, peas, peanuts), soy foods, nuts, seeds, oats
Choline	Legumes (beans, lentils, peas, peanuts), bananas, broccoli, oats, oranges, quinoa, soy foods
Folate	Leafy green vegetables, almonds, asparagus, avocado, beets, enriched grains (breads, pasta, rice), oranges, quinoa, nutritional yeast
Vitamin B12	Fortified foods (nutritional yeast, plant milks), supplement
Vitamin C	Fruits (especially berries, citrus, cantaloupe, kiwifruit, mango, papaya, pineapple), leafy green vegetables, potatoes, peas, bell peppers, chili peppers, tomatoes
Vitamin D	Sun, fortified milks, supplement if deficient
Vitamin K	Leafy green vegetables, sea vegetables, asparagus, avocado, broccoli, Brussels sprouts, cauliflower, lentils, peas, natto (a traditional Japanese food made from fermented soybeans)

dentition or appetite include green smoothies (blended vegetables, fruits, nuts, and seeds), nut and seed butters, bean spreads (e.g., hummus), soups and purees, cooked cereals (whole grains), and nut- and seed-based sauces (Table 3). Food preparation can be simplified by stocking frozen produce (e.g., vegetable or bean burgers, and whole grains); canned legumes and tomatoes, jarred nut and seed butters, sauces (e.g., salsa, marinara), dried legumes, whole grains, and whole grain pastas, and boxed vegetable broths and soups; fortified plant milks, seeds (especially flax, hemp, and chia), tofu, tempeh, and jars of minced garlic and ginger. Further, user-friendly kitchen tools such as a high-powered blender, microwave, rice cooker, electric pressure cooker, and automatic jar opener can improve access to healthful foods.

Table 3. Calorie density.

Food group	Calories per 100 g
Non-starchy vegetables (e.g., broccoli, carrots, beets, okra)	16–49
Fruits (e.g., berries, apples, bananas, tomatoes)	18–89
Starchy vegetables (e.g., potatoes, squash, corn)	17–94
Whole grains (e.g., rice, oats, quinoa)	71–120
Legumes (e.g., beans, lentils, peas)	116–164
Foods made with flour (e.g., bread, bagels, pasta)	149–280
Dried fruits (e.g., dates, prunes, raisins)	240–299
Sugars (e.g., table sugar, maple syrup, agave, corn syrup)	260–399
Nuts and Seeds (e.g., walnuts, cashews, flax seeds)	486–654
Oils (e.g., olive, coconut, canola)	884–892

4 Nutrient adequacy

A common concern when considering any diet, including an entirely plant-based one, is nutrient adequacy. The Academy of Nutrition and Dietetics states in their position paper:[10] "*Vegetarian diets, including vegan, diets are healthful, nutritionally adequate, and may provide health benefits for the prevention and treatment of certain diseases. These diets are appropriate for all stages of the life cycle, including pregnancy, lactation, infancy, childhood, adolescence, older adulthood, and for athletes*." Even calorie-restricted plant-based diets intended for weight loss, have been found to be consistent with dietary guidelines.[76]

5 Plant-based macro-nutrition

The ideal ratio of intake of macronutrients is highly debated. However, it appears that despite nearly a century of macronutrient-centered grouping of food, the quality of the overall diet is likely responsible for health outcomes rather than the more simplistic ratio of macronutrients.

Accordingly, evidence supporting the health and weight management benefits of a whole food, plant-centered plate is abundant.[12,77–79] Much of the benefit may relate to dietary restriction of specific macronutrients (e.g., essential amino acids) and is likely more important than energy restriction alone.[80–83] Dietary restriction has demonstrated improvement in neoplasia, cardiovascular disease, and glucoregulatory impairment in long term primate studies.[84]

Dietary restriction without malnutrition appears to overlap with known cultural loci for centenarian eating patterns such as is demonstrated in the Okinawan diet.[85–87] For example, the Okinawan region of Japan has one of the longest-lived populations in the world, with a high number of centenarians, and a low risk of age-related diseases.[88–90] Their traditional diet is low in calories, very low in fat (especially low in saturated fat), and nutrient-dense, consisting primarily of orange-yellow root vegetables (particularly sweet potatoes), leafy green vegetables, soy foods, and medicinal plants. As their dietary patterns shift away from the traditional plant-centered Okinawan diet and towards a Western one, their life expectancy is declining.[91] Smaller studies suggest coronary artery disease and type 2 diabetes may benefit from a very low-fat diet, but there appears to be more to this benefit than dietary fat percentages alone.[14,30,31] For example, the Mediterranean and certain raw food diets consisting of upwards of 35% of calories from fat show consistent positive health advantages.[92–94]

Recognizing that the traditional categories of protein, carbohydrate and fat may not have enough specificity (i.e., essential versus nonessential amino acids, saturated/trans versus mono/polyunsaturated fats, complex carbohydrates versus simple sugars) to prescribe healthful eating patterns, the Food Triangle (Figure 1) was proposed as an improved way of visualizing and educating people using whole food language.[49,95] The Food Triangle not only addresses energy density, but also conveniently segregates foods based on other nutritional components important to health span and longevity. Bringing the office visit language back to one that is whole-food centered may be helpful and mitigate the confusion and obfuscation that has become the hallmark of food advertising and labeling. However, given the current macronutrient focus, they will be discussed below.

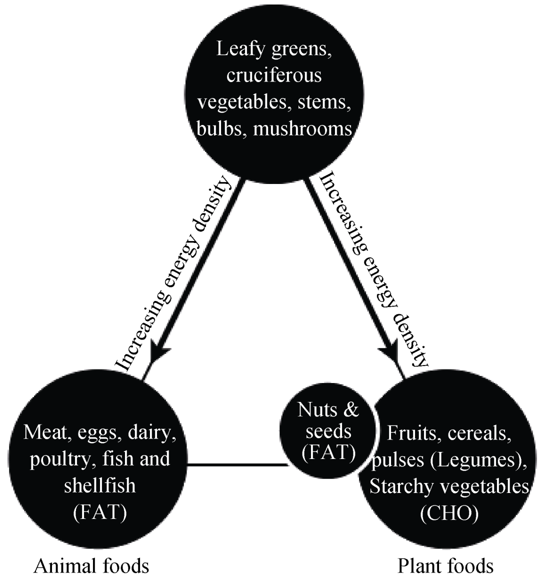

Figure 1. The Food Triangle. The Food Triangle organizes whole food using an energy density paradigm. This organization of energy density permits individuals to address their micronutrient requirements (the apex of the triangle) without driving chronic overnutrition (the bottom vertices of the triangle). These apex foods become the nutritional foundation of daily meals, rather than the more energy dense alternatives. They also provide a rich source of phytonutrients and can be eaten in nearly unlimited quantities. It further places emphasis on foods that are increasingly important for a healthy gut microbiota. Highly refined oils, sugars, and flours are not listed, as they are not whole foods and should be consumed in limited quantities. This image was reproduced with permission from Liebert Publishing.

6 Carbohydrates

The Institute of Medicine (IOM)'s adequate intake (AI) of carbohydrates[96] is 130 g per day for everyone (except during pregnancy and lactation) after the age of one year. Optimal sources of carbohydrates, such as vegetables, fruits, whole grains, and legumes, are high in fiber and other nutrients. Refined carbohydrates from sugars, flours, and other processed foods can lead to malnourishment and promote illness.[97]

Certain foods, for example, whole food tubers like sweet potatoes or cassava, are typically labeled as carbohydrates based on primary energy source. They are traditionally viewed as high in energy and low in protein. However, the opposite is true and these foods are in fact rich sources of protein and low in energy.[98,99] Nitrogen balance is positively maintained even when rice is used as 100 percent replacement for chicken.[100] These results may appear discordant with traditional macronutrient-centered food education, but reinforces the fact that that nutritional requirements can be healthfully met using whole food plant-based sources.

7 Protein

The IOM's AI of protein[96] for adults is based on the recommended 0.8 g/kg per day (about 46 g per day for women and 56 g per day for men). Some research suggests increasing this recommendation to 1.0–1.2 g/kg per day after the age of 65 to reduce the risk for sarcopenia and osteoporosis[101,102] and possibly the risk of cancer and overall mortality.[69] While food marketing and education typically focus on protein from animal sources, all essential amino acids originate with bacterial or plant synthesis and can be obtained from plant sources.[103] Overall, protein is readily available throughout the plant kingdom. Plant-sourced foods that are particularly rich in protein include legumes, nuts, seeds, soy foods, whole grains, and leafy green vegetables. They tend to have lower levels of essential amino acids as compared to animal-based foods, but this difference may be an advantage.[70]

8 Dietary fatty acids

Compared to other nutrient recommendations, the dietary fat acceptable macronutrient distribution range (AMDR) is wide, ranging from 20% to 35% of total calories for adults after 19 years of age.[96] This range is intended to provide enough fat calories as energy while decreasing risk of chronic disease. However, there are more specific guidelines when it comes to the different types of fatty acids, as although they may be isocaloric, they are not isometabolic and hence impart unique influences on health.

Polyunsaturated fatty acids—namely omega-3 and omega-6—are the only essential fats in the diet. Omega-3 fats are found in their shorter chain form as alpha linolenic acid (ALA) and are used as energy and also converted by the body to the longer chain eicosapentaenoic acid (EPA) and then docosahexaenoic acid (DHA).[104] ALA can be found in flaxseeds, hemp seeds, chia seeds, leafy green vegetables (both terrestrial and marine), soybeans and soy products, walnuts, and wheat germ, as well as in their respective oils. A direct plant source of EPA and DHA is microalgal oil, through which fish acquire them.[105–110] Plant sources are superior because they do not contain the contaminants that fish contain, including heavy metals, such as mercury, lead, and cadmium, industrial pollutants like dichlorodiphenyltrichloroethane, polychlorinated biphenyls, and dioxin, and possibly even radioactive isotopes.[111–114] The AI for ALA is 1.1 g per day for adult females and 1.6 g per day for men. Conversion of ALA to EPA and DHA is limited in humans.[115,116] Serum and adipose levels of EPA and DHA have been found to be significantly lower in vegetarians and vegans when compared to omnivores, although there is no evidence of any adverse health or cognitive effects.[117,118] Vegetarians, vegans, and those with reduced conversion ability, such as the elderly, may benefit from doubling the recommended dose of ALA (2.2 g for females and 3.2 g for males per day) and adding a microalgal supplement.[107,119]

As omega-6 fats (linoleic acid), are available ubiquitously in the food supply in the seeds of most plants, they are not a nutrient of concern. In fact, Western diets tend to be excessive in omega-6 fats due to their prevalence in processed foods, which are also low in omega-3 fats. The resultant elevated omega-6/omega-3 ratio has been associated with inflammation and increased chronic disease risk.[120,121] This adverse ratio can be attenuated by ensuring adequate omega-3 intake and minimizing the consumption of highly processed foods.

Mono-unsaturated fats are not essential, but impart either a neutral or slightly beneficial effect on serum cholesterol levels, depending on which nutrient they are replacing. When swapped for saturated or trans fats or refined carbohydrates, monounsaturated fats may lower low density lipoprotein cholesterol (LDL-C) and raise high density lipoprotein cholesterol (HDL-C) cholesterol.[33] These fatty acids are found in olives, avocados, macadamia nuts, hazelnuts, pecans, peanuts, and their respective oils, as well as in canola, sunflower, and safflower oils.

Saturated fats are not essential in the diet and can promote cardiovascular disease.[33,122,123] They are found primarily in animal products, but are available in some plant foods, mostly in tropical fats and oils, such as palm and coconut, and also in other high-fat foods, including avocados, olives, nuts, and seeds. The American Heart Association recommends limiting saturated fat to less than 5 to 6 percent of total calories (about 14 g total on a 2000 calorie per day diet).[124] While recent headlines may cast doubt on the adverse impact of saturated fat, the preponderance of the evidence supports its reduction.[123,125] Underlying mechanisms, metabolic ward studies, and wider observational studies of the last century are still supportive of the reduction of saturated fat.[126–128]

Trans fatty acids (TFAs) are lab-made via hydrogenation and are found in processed, fried, and fast foods. Although they were originally developed to be a healthy alternative to butter and lard, TFAs were found to increase cardiovascular disease risk.[33] In November 2013, the United States Food and Drug Administration (FDA) issued a notice that TFAs were no longer considered safe; the FDA is now trying to eliminate artificially produced TFAs (small amounts are found naturally in some meat and dairy products) from the food supply. Note that a nutritional label can state a food product contains “0 g trans fats” even if it contains up to 0.5 g per serving. Thus, advise patients to focus on the ingredient list on food products and avoid anything with the words “hydrogenated” or “partially hydrogenated.”

Dietary cholesterol is a sterol found only in animal products. Although cholesterol is necessary for the production of hormones, vitamin D, and bile acids, the liver produces adequate quantities of cholesterol and exogenous intake is unnecessary. Dietary cholesterol’s impact on plasma cholesterol is less significant than saturated fat’s, and absorption may be highly individualized, but it nonetheless, may have a significant impact on some individuals and impact may only manifest when individual plasma lipid concentrations are low.[129–132] Saturated fat may potentiate dietary cholesterol absorption and endogenous synthesis.[133,134]

Phytosterols, another class of fats, are plant-based sterols found in all plant foods (especially wheat germ, nuts, seeds, whole grains, legumes, and unrefined plant oils), which are similar to cholesterol. Phytosterols reduce cholesterol absorption in the gut, thereby optimizing lipid profiles. Together with viscous fibers, soy proteins, and almonds, phytosterols have been found to be as effective as statins in lowering LDL-C.[15,60,135,136]

Overall, some dietary fat is necessary to meet the essential fatty acid requirements. Whole food sources of fat (e.g., nuts, seeds, avocados) should be prioritized over processed fats (e.g., oils). Oils provide excess energy (more than 2000 calories per cup) with minimal nutrition including zero fiber.

While nearly a century of macronutrient-centric education has created widespread familiarity with these terms, it may also add a layer of complexity and confusion in chasing mythical macronutrient ratios that seem yet unresolved. Organizing food into isoenergetic macronutrient categories may create a false equivalency of non isometabolic food (e.g., refined sugar versus legumes). This false equivalency may contribute to apparent contradiction in dietary studies and create unnecessary complexity in patient messaging; for example, “choose low glycemic, complex carbohydrates” instead of simple messaging, “eat carrots.” “Eat towards the right side of the Food Triangle” is a simple food-centric instruction that naturally restricts specific deleterious nutrients (e.g., saturated/trans fatty acids, refined sugars, while increasing beneficial nutrients (e.g., dietary fiber, vitamins, minerals, phytonutrients).

9 Plant-based micronutrition

While much of the focus on food centers on the macronutrient content, or energy density, there are many benefits to a whole food, plant-based diet that fall outside of these energy categories. A proper diet should be varied as it is not likely that every micronutrient (e.g., vitamins, minerals, and phytonutrients) is ingested each day. One of the advantages of a fruit- and vegetable-rich diet is the large variety of micronutrient exposure. Beyond the basic vitamin and mineral dietary reference intakes, there are a host of other phytonutrients that may play a significant, but yet not fully understood, role in health. For example, a class of plant-derived compounds, poly-phenols, offers a wide range of antioxidant and other cellular regulatory properties.[137–140] These flavonoids, stilbenes, and curcuminoids have a positive impact on cardiovascular disease, cancer, and neurodegeneration.[141–144] These nutrients are often enzymatic cofactors and may have both additive and synergistic pleiotropic effects that reduce risk of chronic disease.[145–150]

Outside of the emerging science of exotic phytonutrients, fruits and vegetables provide an abundant source of vitamins and minerals. While the vast majority of micronutrients on an exclusively plant-based diet are plentiful, a few need particular attention (of note, there are many micronutrient dietary needs that may be an issue in an omnivorous diet that should be addressed in the elderly population.) Some micronutrient levels may be optimized by adding more vegetables and fruits to the diet and other may require supplementation. The key to success is centered on appropriate periodic testing and avoiding excessive supplementation as has been seen with vitamins A and E.[151,152] We will address notable micronutrients and some suggestions on testing.

10 Vitamin B12

Cobalamin, commonly referred to as vitamin B12, is the only nutrient not directly available from plants. B12 is synthesized by microorganisms, bacteria, fungi, and algae, but not by animals or plants. Animal-sourced B12 results from its natural concentration in flesh, organs and byproducts (e.g., eggs and dairy) after they ingest these microorganisms along with their food. Vitamin B12 deficiency poses an adverse threat of potentially irreversible neurological disorders, gastrointestinal problems, and megaloblastic anemia. B12 deficiency, however, is not unique to vegans who do not supplement. In fact, deficiency is prevalent in the elderly population, due to inadequate intake or absorption. The body can store vitamin B12 for approximately three to five years, or even up to ten years, but without repletion or an ability to absorb, deficiency ensues.[153–156] Often, symptoms are either subclinical or subtle and nonspecific. Due to this lag time and because serum tests for B12 levels (including serum cobalamin, serum methylmalonic acid, and Schilling test) can be skewed by other variables, irreversible damage may occur before a deficiency is caught.

In a plant-based diet, vitamin B12 can be found in fortified plant milks, cereals, and nutritional yeast. Since absorption varies greatly depending on the dose and the individual, it is recommended to supplement with greater than the Recommended Daily Allowance (RDA) to ensure adequate intake.[157] The daily RDA for adults is 2.4 µg and weekly is 16.8 µg, which can be accomplished by a 50 µg dose twice a day, 150 µg once a day, or 2500 µg once a week.[157,158] The standard treatment for B12 deficiency is parenterally administered cyanocobalamin.[159–162] No tolerable upper limit for B12 has been established and high doses are considered safe, but periodic testing and dosage adjustment is recommended.[163] Since accurate diagnosis of B12 deficiency is challenging, symptoms are nonspecific, prevalence is common, and treatment is safe and effective, it is recommended that vegans and even all adults over the age of 60 years supplement to avoid deficiency.[164]

11 Vitamin D

Vitamin D, or calciferol, is also known as the "sunshine vitamin" since it is the only nutrient that is acquired from the sun. Although vitamin D is considered a fat-soluble vitamin, it is actually a prohormone produced in the skin upon exposure to ultraviolet B (UVB) sun radiation and then activated by the liver and kidneys.

Despite the fact that bodies evolved to absorb vitamin D via the sun, there appears to be a worldwide epidemic of deficiency. In the geriatric population, deficiency has been associated with an increased risk for cognitive impairment, secondary hyperparathyroidism and its resultant osteoporosis, falls, and fracture risks, certain cancers, type 2 diabetes, cardiovascular disease, and autoimmune disease.[165–171]

Aging significantly decreases the capacity of the skin to produce vitamin D, particularly with limited exposure to UVB rays.[10,168,170]

Furthermore, vitamin D is not widely available from the food supply. Sources of preformed vitamin D include fish liver oil, oily fish, liver, and in smaller doses, meat and egg yolk. Vitamin D from sunshine and animal sources is in the form of cholecalciferol, or vitamin D3. An additional form called ergocalciferol, or vitamin D2, is found in plant sources, mostly in UVB-irradiated mushrooms. However, there is a more recently discovered plant-derived version of D3 made by lichen. Dietary supplements may contain either D2 or D3, both of which can be effective at raising blood levels.

Some physicians test for serum levels of vitamin D with the 25-hydroxyvitamin D test. As vitamin D is fat-soluble and excess levels can result in toxicity, it is preferable to monitor vitamin D levels in order to avoid deficiency. The Institute of Medicine concluded that adequate serum 25-hydroxyvitamin D levels of at least 20 ng/mL (50 nmol/L) meet the needs of about 97.5% of the population and is considered adequate for bone and overall health in healthy individuals.[172]

If patients have suboptimal levels, emphasizing food sources (especially fortified plant milks) as well as sun therapy may prove effective as a first line of treatment. Supplementation may be reasonable if levels remain low.

12 Vitamin K

Vitamin K is necessary for blood coagulation, cardiovascular health, and bone strength. Although vitamin K1, phylloquinone, is abundantly available in leafy green vegetables, there is increasing evidence that vitamin K2, menaquinone, is also necessary. Produced by microorganisms as well as converted from K1 by intestinal bacteria in small amounts, supplementing with a direct source of K2 may be beneficial.[173–177]

13 Calcium

Calcium is the most abundant mineral in the human body, with 99 percent stored in the bones and teeth and the remaining one percent circulating in the blood and tissues. Calcium is a nutrient of concern for the general population with respect to bone mineral optimization over the lifespan. However, because bone metabolism is multi-factorial and complex, it is important to emphasize ample sources of calcium as well as vitamins K and B12, fluoride, magnesium, phosphorus, and potassium; to maintain serum vitamin D levels; and to ensure regular resistance exercise.

To maximize absorption, frequent consumption of calcium sources spread throughout meals is recommended; prioritize low oxalate leafy greens such as bok choy, broccoli, napa cabbage, collard greens, dandelion greens, kale, turnip greens, and watercress; be wary of excessive intakes of sodium, protein, caffeine, and phosphorus (as from sodas); and ensure normal serum vitamin D levels.[178]

14 Iron

Although iron is one of the most abundant metals, iron deficiency remains one of the most common and widespread nutritional deficiencies, with prevalence increasing with age.[179,180] Iron-deficiency anemia is no more common in vegetarians than in non-vegetarians and vegetarian diets typically include the same or higher amounts of iron than non-vegetarian diets.[181–183]

Plant-sourced iron is non-heme, which is susceptible to compounds that both inhibit (e.g., phytates and polyphenolics) and enhance (e.g., vitamin C and organic acids) its absorption. However, individuals adapt absorption of non-heme iron more effectively than heme iron and are able to adapt to low iron intakes over time.[10,184,185]

There is a wide array of iron-rich food choices in the plant kingdom. Leafy greens and legumes are excellent sources of iron and myriad other nutrients, so it is advantageous to include these foods often. Other good choices include soy products, dark chocolate, blackstrap molasses, tahini, pumpkin seeds, sunflower seeds, raisins, prunes, and cashews. In order to enhance absorption, consume iron-rich foods in combination with foods high in vitamin C- and organic acid-rich foods. This combination improves solubility, thereby facilitating absorption. Examples include a green smoothie with leafy greens (iron) and fruit (vitamin C), salad greens (iron) with tomatoes (vitamin C), or a bean-based chili (iron) with tomato sauce (vitamin C).

15 Iodine

Dietary plant sources of iodine, a trace mineral, are unreliable due to varying soil qualities. Available options include iodized salt and sea vegetables. One half teaspoon of iodized salt provides the daily recommended 150 µg dose.[186] Importantly, iodine levels in sea vegetables fluctuate dramatically, with some (especially dulse and nori) containing safe amounts and others (such as kelp) harboring toxic doses.[187] Hijiki, also spelled hiziki, should be avoided due to its excessive arsenic levels.[188] However, for those avoiding iodized salt (e.g., patients with hypertension or people opting for gourmet, non-iodized salts) and also not regularly consuming sea vegetables, iodine deficiency and the risk for thyroid issues are a concern. A pre-existing iodine deficiency, a selenium deficiency, or high intake of goitrogens (antinutrients found in cruciferous vegetables, soy products, flaxseeds, millet, peanuts, peaches, pears, pine nuts, spinach, sweet potatoes, and strawberries) can interfere with iodine absorption. There is no need to avoid goitrogenic foods as long as iodine intake is sufficient. If a patient does not enjoy sea vegetables or is minimizing intake of salt, an iodine supplement may be warranted.[189,190]

16 Selenium

Selenium is an essential trace mineral that plays a role in thyroid hormone regulation, reproduction, and DNA synthesis and also exerts powerful antioxidant, antiviral, and anti-inflammatory effects.[191] Brazil nuts are an especially rich source of selenium in the plant kingdom. Just one ounce (approximately 6 to 8 nuts) provides 777 percent of the RDA. When accessible, one Brazil nut a day is an ideal way of meeting selenium recommendations. In a randomized crossover trial involving 15 men and women, a single dose (20 g) of Brazil nuts (about 4 nuts) reduced LDL-C by about 22 mg/dL and increased HDL-C by nearly 20 mg/dL 30 days later.[192] Other plant sources include whole grains, legumes, vegetables, seeds, and other nuts.

17 Zinc

Zinc supports immune function and wound healing; synthesis of protein and DNA; and growth and development throughout pregnancy, childhood, and adolescence.[193] Zinc status in vegetarians is similar, or somewhat lower, than that of non-vegetarians because of the decreased bioavailability of zinc in plant foods due to their phytate content. However, there do not appear to be adverse health consequences of these lower levels, suggesting increased efficiency of absorption with adaptation to long-term vegetarian diets.[194] Zinc deficiency may be difficult to detect in blood tests but can show up clinically as delayed wound healing, growth retardation, hair loss, diminished immunity, suppressed appetite, hair loss, taste abnormalities, or skin or eye lesions. Advise patients to include legumes, cashews and other nuts, seeds, soy foods, and whole grains. Preparation methods such as soaking, sprouting, leavening, and fermenting will help improve absorption.

18 Note on supplements in general

Because the supplement industry is not regulated by the FDA, it is buyer beware in the supplement market.[195] Thus, aim to find reputed companies. A few organizations, such as Consumer Lab, NSF International, and U.S. Pharmacopeia, act as independent third parties and offer seals of approval after testing products for potency and contaminants. They do not, however, test for safety or efficacy.

19 Conclusions

A plant-based diet is beneficial throughout the lifespan, and may be particularly useful in the elderly population. Evidence from prospective cohort studies suggests that a diet rich in vegetables, fruits, whole grains, legumes, nuts, seeds, herbs, and spices is associated with a significantly lower risk of cardiovascular disease; the protective effects of these foods are likely mediated through multiple beneficial nutrients. A plant-based diet can meet energy and satiety needs and is ideal for the elderly population as it involves simple food preparation, easily digested balanced meals, and, if required, may be easily blended into a flavorful and nutritious liquid diet.

Making a significant change in diet and lifestyle can be difficult at any age, especially when the new diet may not at first appear equally familiar, convenient and enjoyable to the Western diet. A survey of human populations in both time and culture, however, reveals that normal has a wide range of what might be considered palatable. Wilbur O.

Atwater, a leading 19th century nutritionist, wrote: "*In our practice of eating, we are apt to be influenced too much by taste [and] the dictates of the palate; we are prone to let natural instinct be overruled by acquired appetite. We need to observe our diet and regulate appetite by reason. In doing this we may be greatly aided by the knowledge of what our food contains and how it serves its purpose in nutrition.*"[196] This is still true today, despite knowing more about food than any time in human history.

This brings us back to a critical person in the dietary transformation, the attendant physician. As was clear in the very successful campaign to adjust the social habits surrounding smoking, a highly addictive activity that most physicians practiced at that time, each of us providing nutritional advice must look at our own diet.

Ultimately the dietary change needed in society requires the leadership of all healthcare professionals. A whole food, plant-based diet pattern can be easily achieved and is at least one solution to the tremendous socioeconomic burden that nutritionally-induced, non-communicable chronic diseases places on all of humanity.

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