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VEGETARIAN AND VEGAN DIETS FOR ATHLETIC TRAINING AND PERFORMANCE

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- Vegetarian diets are selected by athletes for a variety of reasons including health, environmental, ethical, philosophical, religious/spiritual and esthetics.
- Although research strongly suggests that plant-based vegetarian and vegan diets may offer many health benefits to athletes and nonathletes alike, there is currently little evidence that vegetarian diets per se are better than omnivorous diets for improving athletic training and performance.
- Athletes at all levels, from youth to recreational to elite, can meet their energy and nutrient needs on a vegetarian or vegan diet that contains a variety of foods, including grain products, fruits, vegetables, protein-rich plant foods, and (if desired) dairy products and eggs.
- Athletes with high-energy requirements may need to eat frequent meals and snacks and limit fiber-rich foods. Meeting energy requirements is crucial for obtaining proper nutrition to optimize training adaptation and performance.
- Certain nutrients including protein, omega-3 fatty acids, calcium, vitamin D, iron, zinc, iodine, vitamin B-12 and riboflavin are found less abundantly in plant, compared to animal, foods, or are less well absorbed. The selection of foods containing these nutrients typically ensures adequate status; however, judicious supplementation of these nutrients may occasionally be needed.
- Like most athletes, vegetarian athletes may benefit from education about food choices to optimize their health and performance.

INTRODUCTION

Athletes elect to follow vegetarian diets for health, environmental, ethical, philosophical, religious/spiritual and esthetic reasons, which can include the dislike of meat. Although vegetarian diets are well-accepted in the public health arena, some coaches and professionals express concern that vegetarian athletes may not receive the proper nutrition required for optimal training and performance. In truth, vegetarian athletes, from recreational to elite, can meet their energy and nutrient requirements on the various types of vegetarian diets (Table 1). Athletes may at the same time lower their risk for chronic diseases (Dinu et al., 2017; Melina et al., 2016), and enhance their ability to perform optimally or recover from strenuous exercise. To ensure optimal performance, vegetarian athletes need to consume adequate energy and select foods rich in the "red flag" nutrients, which either are found less abundantly in vegetarian foods or are less well absorbed from plant compared to animal sources. Like most athletes, vegetarian athletes may benefit from education about food choices to optimize their health and performance (Melina et al., 2016; Thomas et al., 2016).

Vegan (strict vegetarian)	Excludes all animal products including dairy and eggs; may exclude honey
Vegetarian	Avoids all flesh foods; may or may not consume eggs or dairy products
Lacto-vegetarian	Includes milk or other dairy products but not eggs or other animal foods
Ovo-vegetarian	Includes eggs but not dairy products
Lacto-ovo-vegetarian	Includes eggs and dairy products

Table 1. Types of vegetarian diets.

This article will discuss the use of vegetarian diets among athletes, review the energy and macronutrient needs of athletes and active individuals, and address the specific vitamins and minerals that may be lacking in a poorly selected vegetarian diet. Tips for professionals to consider when working with vegetarian athletes are also addressed.

VEGETARIAN DIETS IN PERSPECTIVE

Trends in Vegetarian Diets

Although interest in plant-based diets among athletes is not new (Grandjean, 1987; Longo et al., 2008; Nieman 1988), there "appears" to be a recent increase in the popularity of such diets among athletes, particularly for vegan diets (Table 1). Little is known, however, about the prevalence of vegetarianism among athletes. Among the general population, recent nationwide polls in the U.S. suggested that ~3.3% of adults are vegetarian or vegan (report never eating meat, poultry or fish) and about 46% of vegetarians are vegan (Vegetarian Resource Group, 2014; 2016). The same poll revealed that 6% of young adults aged 18 to 34 years were vegetarian or vegan while an earlier poll specifically in youth found that ~5% of high school students in grades 9-12 were vegetarian or vegan (Vegetarian Resource Group, 2014). In contrast, only 2% of those 65 years or older are vegetarian. Among athletes, a survey of contestants at the 2010 Commonwealth games found that

8% of international athletes reported eating vegetarian diets, with 1% being vegan (Pelly & Burkhart, 2014).

Potential Benefits of Vegetarian Diets

Vegetarian diets may have many health advantages over the typical Westernized diets. Vegetarian and vegan diets are associated with a reduced risk for a variety of chronic diseases including obesity, hypertension, hyperlipidemia, cardiovascular disease, type 2 diabetes and overall cancer mortality (Melina et al., 2016; Thomas et al., 2016). Less is known about the ability of these diets to enhance training or sports performance (Craddock et al., 2016; Nieman, 1988; Thomas et al., 2016). Results from observational and short-term intervention studies in which subjects consumed vegetarian or non-vegetarian diets for test periods of several weeks have detected no difference in strength/power, aerobic and anaerobic performance parameters based on the presence or absence of animal-derived (mostly flesh) foods (Craddock et al., 2016). Nevertheless, it has been hypothesized that vegetarian diets help athletes optimize their training and performance (Craddock et al., 2016) due to the naturally high content of carbohydrate (Nieman, 1988), antioxidants and other phytochemical (Trapp et al., 2010), and even the alkaline earth metal strontium (Longo et al., 2008). Vegetarian diets may also produce an ergogenic advantage by inducing a slight serum alkalinity during exercise (Hietavala et al., 2015). The higher content of antioxidants in particular may help reduce oxidative stress associated with prolonged exercise and modulate immune function and inflammation (Trapp et al., 2010). It is not yet established, however, whether long-term consumption of a vegetarian diet would enhance recovery, prevent inflammatory (or overuse) injury, and attenuate the oxidative damage that occurs with heavy training (Trapp et al., 2010), or induce enough of a serum alkalinizing effect to buffer acid production during intense exercise and thereby enhance athletic performance (Hietavala et al., 2017). Despite the ergogenic potential, however, a vegetarian diet may also have the potential to impair both health and performance if food choices are consistently suboptimal.

NUTRIENT CONSIDERATIONS AND RECOMMENDATIONS

Energy and Macronutrients

Energy: Meeting energy needs is a nutrition priority for all athletes (Thomas et al., 2016). Inadequate energy intake negates the benefits of training, compromises performance and may result in health complications that include a loss of muscle mass and/or bone density, and an increased risk of fatigue, injury and illness. Energy requirements vary among individual athletes according to the specific sport, intensity and periodized training activities at which athletes participate (which are likely to vary from day to day and across the season). Other influencing factors include sex, age and body composition. Some vegetarian and vegan athletes may not meet their energy needs due to the high-fiber and low-energy density of plant-based diets combined with elevated energy needs and/or hectic schedules that prohibit adequate time to eat. Athletes with high-energy needs should be encouraged to eat frequent meals and snacks (i.e., ~5-8 meals/snacks/day) and adequately plan so food and snacks are readily available. For example, snacks or mini-meals packed in a gym bag, back pack or kept in a locker or desk drawer provide readily available food energy. Selection of energy-dense foods and limiting of fiber-rich foods may also help meet energy needs. For example, replacing some whole fruit servings with fruit juice and consuming one-third to one-half of grains, cereals and breads as less processed sources, such as white rice or sourdough bread rather than brown rice or whole wheat bread will reduce excessive fiber intake and the early onset of satiety (Grandjean, 1987; Larson-Meyer, 2007). In contrast, other vegetarian athletes may require lower energy intakes to promote a slow and sustained weight reduction for health and/or performance reasons. These athletes may benefit from an emphasis on the selection of whole, unprocessed foods to promote satiety and help in achievement of a healthy body weight.

	Lacto-Ovo Vegetarian	Vegan
Breakfast 2 ounce Grains 2 ounce Proteins ½ cups Vegetables 1 cup Fruit ½ cup Diary/Eq	2 slices Whole Wheat Toast Butter & 1 Tbsp Fruit Preserves 2 Scrambled Eggs ½ cup Peppers & Spinach 1 cup Orange Juice Latte made with ½ cup Milk	2 Slice Whole Wheat Toast Margarine & 1 Tbsp Fruit Preserves ½ cup Scrambled Tofu ½ cup Peppers & Spinach 1 cup Calcium-Fortified Orange Juice Latte made with ½ cup Soymilk
Lunch 2 ounce Grains 2 ounce Proteins 1 cup Vegetables 1 cup Fruit ½ cup Diary/Eq	2 slices Sourdough Bread 2 cups Minestrone Soup (made with 1/4 cup garbanzo beans, ¼ cup kidney beans, 1 cup mixed vegetables & olive oil) topped with ½ ounce Parmesan Cheese Large Apple	2 slices Sourdough Bread 2 cups Minestrone Soup (made with 1/4 cup garbanzo beans, ¼ cup kidney beans ¾ cup mixed vegetables/ ¾ cup vale & olive oil) Large Apple
Snack 2 ounce Grains 1 ounce Proteins ½ cup Diary/Eq	½ Large (2 oz) Whole Grain Bagel 1 Tablespoon Peanut Butter 1 cup Milk	½ Large (2 oz) Whole Grain Bagel 1 Tablespoon Peanut Butter 1 cup Soymilk
Dinner 4 ounce Grains 2 ounce Protein 2 ½ cups Vegetables	4 Lentil Tacos (made with lentils, tomato sauce, canned tomatoes, onion, celery and canola oil on soft corn tortillas served with lettuce, jicama, fresh tomato, avocado and salsa)	4 Lentil Tacos (made with lentils, tomato sauce, canned tomatoes, onion celery and canola oil on soft corn tortillas served with lettuce, jicama, fresh tomato, avocado and salsa)
Snack 1 cup Diary/Eq	1 cup Yogurt ½ cup Berries or sliced Peaches	1 cup Rice Yogurt ½ cup Berries or sliced Peaches
Exercise Associated Snacks	Fluid replacement beverage, sports gels, sports bars, etc.	Fluid replacement beverage, sports gels, sports bars, etc.

Table 2. Sample 3,000 Kcal Lacto-Ovo and Vegan Diet.

Many publicly available food guidance systems geared at athletes, vegetarians or the general public may be useful for helping educate vegetarian and vegan athletes on healthy eating patterns that meet energy needs. These include USDA's MyPlate, which has adjustments for energy requirements and tips for vegetarian diets (United States

Department of Agriculture), the United States Olympic Committee Sports Dietitians Athlete's Plates (which are based on training phase and easily adopted to vegetarian patterns) (The United States Olympic Committee Sports Dietitians; The University of Colorado Sports Nutrition Graduate Program, 2006), and the guidelines developed specifically for vegetarian athletes (Larson-Meyer, 2007). Vegetarian or vegan-specific eating plans, such as The Vegetarian Resource Groups "My Vegan Plate" (Vegetarian Resource Group, 2011), may also provide a useful framework if the number of servings is appropriately adjusted to meet the higher energy demands of many athletes. A sample 3,000-kcal menu created for a vegetarian and vegan athlete using USDA's MyPlate as the template is provided in Table 2.

Carbohydrate: Carbohydrates are an important component of an athlete's diet and should make up the bulk of their energy intake. Carbohydrate ingestion is essential for optimal performance during prolonged moderate- to high-intensity exercise lasting longer than ~90 min and during intense intermittent activities, which are typical of many team sports (Burke et al., 2011, Thomas et al., 2016). Carbohydrates are also necessary for glycogen repletion following exercise and to ensure adequate adaptation to training. The amount of carbohydrates that active vegetarians need to ingest varies, depending on sport, intensity and body mass (BM). The current carbohydrate recommendations are 5-10 g carbohydrate/kg BM/day for most athletes performing moderate- to high-intensity exercise of ~1-3 h/day (Thomas et al., 2016). Lower intakes of 3-5 g/kg BM are suggested for athletes performing low-intensity or skill-based training while higher requirements of 8-12 g/kg BM are recommended during extreme endurance training (Burke et al., 2011; Thomas et al., 2016). Although the typical vegetarian diet is packed with carbohydrate, the importance of achieving adequate carbohydrate is emphasized here in light of the recent popularity of lower carbohydrate diets that also may be "attractive" to certain vegetarian athletes. Vegetarian athletes, like all athletes, should be educated on the proper types of carbohydrates to eat surrounding an exercise session.

Protein: Protein requirements vary according to training level and type of activity. An athlete undergoing intense training will need more protein than a person who is recreationally active and exercises moderately several days a week. The US Recommended Dietary Allowance (RDA) of 0.8 g protein/kg BM/day should meet the needs of most people who exercise at a light to moderate intensity most days of the week (Otten et al., 2006). Athletes who train at higher intensities generally need more protein. Emerging research on protein requirements of athletes suggests that dietary protein interacts with exercise providing not only a substrate for the synthesis of contractile, structural and metabolic proteins but also a trigger for muscle protein synthesis (Phillips & van Loon, 2011; Thomas et al., 2016). The current protein intake recommendations for athletes is 1.2-2.0 g protein/kg BM/day (Thomas et al., 2016) which is recommended to support metabolic adaptation, repair, remodeling and protein turnover.

There is little evidence to suggest that the protein requirements for athletes following vegetarian diets are different from those following omnivorous diets, particularly given the large range suggested by the current protein requirements for athletes. To ensure adequate protein intake, vegetarian athletes should be encouraged to consume a variety of plant-based protein-rich foods and ensure adequate energy intake. Good sources of plant-based and vegetarian proteins (> 7 g protein/serving) are shown in Table 2, however, it is important to remember that all grains, cereals and starchy vegetables also contribute small amounts of protein (2-3 g/serving). Vegetarians do not need to consume specific combinations of plant-based protein at each meal but should consume a variety of protein sources spread throughout the day (Melina et al., 2016; Young & Pellett, 1994). One exception may be in the post-exercise period for athletes undergoing intense muscle-based training where a certain concentration of serum leucine and ~10 g of essential acids may be necessary to optimize muscle protein synthesis in the immediate post-exercise period (Phillips & van Loon, 2011; Thomas et al., 2016). Many plant proteins including legumes are leucine-rich, albeit not as well absorbed as whey protein. Furthermore, usual culinary combinations of protein such as beans and rice, beans and nuts/seeds (e.g., in hummus) or a peanut butter sandwich tend to be complementary (Young & Pellett, 1994)

Fat: Fat intake guidelines for athletes should be in accordance with public health guidelines, and be individualized based on training and body composition goals (Thomas et al., 2016). Dietary fat is necessary in order to provide energy, elements of cell membranes and essential fatty acids, and to aid in the absorption of fat-soluble vitamins. Fat stored within active muscle and adipocytes is used as a substrate during prolonged exercise of moderate-intensity and during low-level activity. Thus, dietary sources of essential fatty acids should be emphasized to meet intake recommendations and saturated fat be limited to less than 10% of total energy intake (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2011). Both chronic low-fat intake below 20% of energy and strategies which promote low-carbohydrate, high-fat diets for purported performance benefits are discouraged (Thomas et al., 2016). Although extremely low-fat vegan diets (< 10% energy from fat) are recommended for the prevention and treatment of cardiovascular disease and diabetes (McDougall et al., 2014), such diets are too restrictive for athletes undergoing intense training regimens. The currently popular trend of fat adaptation to enhance fat oxidation via extremely high-fat, low-carbohydrate diets has been shown to down regulate carbohydrate metabolism and compromise performance during the high-intensity exercise bouts that are common in most sports (Burke, 2015; Thomas et al., 2016).

Vegetarian and vegan athletes can ensure that fat intake is appropriate within the guidelines through judicious selection of plant-based sources (Table 3) and low- or full-fat dairy products, as desired. In general, however, the vegetarian diet is rich in omega-6 polyunsaturated fatty acids but limited in omega-3 fatty acids (Li, 2003). Lacto-ovo diets can also provide excessive saturated fat if intake of animal-derived fats

Protein	Functional and structural components of the body;in athletes serves as trigger and source for muscle protein synthesis	Milk, yogurt, cottage cheese, cheese, eggs, beans, peas, lentils, edamame, tempeh, tofu, soy products (veggie burgers, dogs, other meat analogues), nuts, seeds, nut butters (including peanut), soymilk and other plant-based "milks". Other sources: starchy vegetables, grains including breads, rice, quinoa, oatmeal.
Healthy Fats	Energy source; aids in absorption of fat-soluble vitamins	Nuts, seeds, nut butters, avocado, olives, olive oil, flax seed, coconut, granola and muesli cereals, plant based oils including canola, grape seed, hazelnut, sesame seed, pumpkin seed and hemp oils.
Omega-3 Fatty Acids	Modulation of inflammatory process	Walnuts, flax, chia, camelina and hemp seed, and canola, walnut, flax and hemp oils.
Iron	Component of hemoglobin and myoglobin and as part of cytochromes and enzymes in energy-yielding pathways	Beans, peas, lentils, edamame, nuts, seeds, most vegetables, whole & fortified grains including breads, rice, quinoa, breakfast cereal. Absorption enhanced by consuming with source of vitamin C: citrus fruits, berries, melon, peppers, tomatoes, broccoli, kale, potatoes.
Zinc	Component of many enzymes including those involved in energy metabolism, protein synthesis and immune function	Beans, peas, lentils, edamame, nuts, seeds, most vegetables, whole & fortified grains including breads, rice, quinoa, breakfast cereal, hard cheeses.
Calcium	Growth, nerve conduction, maintenance and repair of bone tissue, regulation of muscle contraction and normal blood clotting	Excellent bioavailability (> 50%): Chinese/Napa cabbage, bok choy, collards, kale, okra, turnip greens, texturized vegetable proteins, black strap molasses. Average bioavailability (~30%): Milk, yogurt, cheese, calcium-set tofu, fortified orange juice (with calcium citrate malate). Lower bioavailability: fortified soymilk, most nuts, seeds legumes, fortified orange juice (with tricalcium phosphate/calcium lactate).
Vitamin D	Calcium absorption, bone health, skeletal muscle function, immune function, inflammatory modulation	Fatty fish, eggs from hens fed vitamin D or exposed to sunlight, vitamin D-fortified breakfast cereals, margarine, fruit juice and plant-based "milks." Exposure of the arms, torso and legs, two to three a week, at close to solar noon for 25 to 50% of the time it would take to develop a mild sunburn.
Iodine	Functions as part of thyroid hormone, which is a key regulator of metabolism and heart rate	Iodized salt, fish, seafood, seaweed, dairy products and some commercial-breads.The iodine content of most foods is low and affected by soil content, irrigation and fertilizers.
Vitamin B12	Important for energy production	Redstar™ nutritional yeast, soymilk & plant-based "milks," breakfast cereals and B-12 fortified meat analogs (veggie burgers, veggie dogs, etc.).
Riboflavin	Coenzyme for numerous oxidation- reduction reactions in several metabolic pathways and in energy production	Milk and milk-based drinks, bread products and fortified cereals; small amounts found in most plant foods.

Table 3. Vegetarian Sources of Key Nutrients.

including cheese and other full-fat dairy products and eggs are consumed regularly. Because omega-3 fatty acids may be important for inflammatory modulation (Thomas et al., 2016), vegetarian athletes may benefit from intentional selection of omega-3 rich foods (Table 3) in place of some or in addition to omega-6 rich oils (corn, cotton seed, sunflower and safflower). Even though endogenous elongation of alpha-linolenic acid (ALA) to eicosapentaenoic acid (EPA) is inefficient and influenced by health status, sex, age and diet composition (its conversion is increased when omega-6 concentrations are low), evidence suggests that omega-3 needs can be met with ALA alone (Melina et al., 2016). Endogenous synthesis of EPA and Docohexanoic acid (DHA) from ALA appears to be sufficient to maintain long-term stable concentrations in vegetarians. Vegetarian athletes may also consider DHA-rich microalgae supplements (Geppert et al., 2005), which are well-absorbed and increase DHA and EPA concentrations in blood. Athletes habitually obtaining more than 10% of energy from saturated fat should replace some servings of full-fat dairy and/or eggs with plant-based sources (Melina et al., 2016).

Vitamins and Minerals: Vitamins and minerals are an essential part of the diet of all athletes. Vegetarian athletes may need to pay particular attention to a handful of nutrients which are either found less abundantly in vegetarian foods or are less well absorbed from plant compared to animal sources. These nutrients include iron, zinc, calcium, vitamin D, iodine and some of the B-vitamins (B-12 and riboflavin). Other nutrients including potassium, magnesium, folate, vitamins A, C, E and K are typically provided abundantly by a well-balanced vegetarian diet (Melina et al., 2016).

Iron: Iron intake can be a concern for vegetarian athletes, particularly female athletes. Non-heme iron (plant-based iron) is best absorbed with foods that contain ascorbic acid (i.e., citrus fruit or juice, tomatoes and melon) and other organic acids and is inhibited by plant phytates, polyphenolics, tannins in tea, cocoa and coffee, soy and dairy protein, and foods with high concentrations of calcium, zinc or other divalent minerals (Otten et al., 2006). Cooking with iron cookware also boosts iron content, particularly when the foods are slightly acidic (i.e., tomato sauce). If iron status is a concern, the sports dietitian or physician should assess whether iron supplementation is needed (Maughan et al., 2018). High-dose iron supplements should not be taken unless iron deficiency is present, as it may interfere with absorption of other minerals (Otten et al., 2006) and can lead to excess iron stores in individuals at risk for hemochromatosis.

Zinc: Like iron, suboptimal zinc status may be somewhat prevalent in certain athletes, including female athletes and athletes following vegan and vegetarian diets. In vegetarians, lower zinc status may be attributed to the selection of zinc-poor foods or the reduced bioavailability of zinc from plant compared to animal foods (Melina et al., 2016). Vegetarians who eat a varied and well-balanced diet that contains many zinc-rich plant foods (Table 3) including legumes and whole grains are likely to achieve adequate zinc status without dietary supplementation (Hunt et al., 1998). Similar to iron, organic acids such as citric, malic and lactic acids can enhance zinc absorption to some extent (Lonnerdal, 2000), whereas food preparation techniques such as soaking, sprouting of beans, grains, nuts and seeds, and leavening bread can reduce binding of zinc by phytic acid (Melina et al., 2016; Otten et al., 2006).

Calcium and Vitamin D: Calcium intake is a concern for vegan athletes and vegetarians who consume minimal dairy products. Although it is possible for vegetarians, including vegans, to meet recommendations for calcium, judicious selection of well-absorbable sources of calcium along with possible use of calcium-fortified foods can help ensure calcium adequacy (Mangels, 2014) Plant foods that are rich in well-absorbable calcium are listed in Table 3. The calcium bioavailability of most of these plant foods is as good as or better than cow's milk, which has a fractional absorption of 32% (Weaver et al., 1999) (Table 2). Exceptions include spinach, chard, beet greens and rhubarb, which have a low bioavailability (< 5-8%) due to the high oxalate content of these foods. Vitamin D, which aids in calcium absorption, may also be a concern for some athletes due to limited sun exposure and/or reduced intake of Vitamin D-containing foods. While vegetarians and vegans may be at additional risk due to lower dietary intake (Crowe et al., 2011), factors such as skin pigmentation, sun exposure intensity and dietary supplementation are more important predictors of vitamin D status than is intake from food sources (Chan et al., 2009). Vitamin D requirements can be met by exposing arms, legs and abdomen and back (i.e., in shorts and a sports bra) to noontime sunlight for ~10-30 min several times a week depending on skin pigmentation (Hossein-Nezhad & Holick, 2013) (Table 3). Supplementation (1,000-2,000 IU/day) may be beneficial, especially for athletes living at extreme latitudes (> 35 degrees north or south latitude), who train primarily indoors, use excessive sunscreen or have excess body fat, dark pigmented or very fair skin or photosensitivity. Vegans can be directed to look for vitamin D-3 derived from lichen, rather than lanolin, and D-2 produced from irradiation of yeast ergosterol (Mangels, 2014). Research has suggested, however, that vitamin D-2 may be less effective than vitamin D-3 when taken in higher doses (> 4,000 IU).

Iodine: Poor iodine status is common in many vegans and vegetarians who do not consume table salt (typically fortified with iodine) or sea vegetables, or consume plant foods grown in iodine-poor soil (Krajcovicova-Kudlackova et al., 2003, Melina et al., 2016). There is also some evidence that iodine is lost in sweat which may place athletes who sweat heavily at additional risk for suboptimal status (Smyth & Duntas, 2005). Adequate iodine status can be assured by encouraging athletes to use iodized salt in cooking and salting foods (1/2 teaspoon or 3 g provides close to the RDA and 1,180 mg sodium) along with appropriately reducing intake from processed foods (see Table 3 for additional sources). Sea salt, gourmet salts, most salty seasonings (tamari, soy sauce) and most sodium-containing processed foods are not iodized.

Vitamin B-12 and Riboflavin: Athletes who follow vegan or near vegan diets are at risk for low vitamin B-12 status (Pawlak et al., 2013), which is found exclusively in animal products (Melina et al., 2016). Vegan athletes should consume vitamin B-12 fortified foods daily or take a vitamin B-12 containing supplement or multivitamin. Vegetarian athletes should also consider taking a supplemental source if their intake of dairy products and/or eggs is limited. Riboflavin may also be a concern to vegan and vegetarians who limit intake of dairy (Herrmann & Geisel, 2002) and possibly also restrict energy intake. The best sources of these vitamins and minerals for vegans and vegetarians are listed in Table 3.

OTHER NUTRITIONAL ASPECTS OF VEGETARIANISM RELEVANT TO ATHLETES

Avoiding Low Energy Availability in Vegetarian Athletes

Athletes pressured to succeed in sports by achieving (or maintaining) an unrealistically low body weight through food restriction and/or excessive exercise are at risk for disorders of low energy availability currently termed relative energy deficiency in sport (RED-S) (Thomas et al., 2016). There is some evidence that RED-S (formerly referred to as the Female Athlete Triad) or its individual components, endocrine disturbances, low bone density, disordered eating and other physical factors, may be more common among vegetarian athletes (Larson-Meyer, 2018). Experts agree, however, that the apparently higher prevalence among vegetarians is because vegetarianism is often used as a socially acceptable way to restrict food intake and mask an eating disorder (Barnard & Levin, 2009). Among non-athletic individuals, semi vegetarians rather than true vegetarians had the greatest risk of disordered eating patterns (Timko et al., 2012). An increased prevalence of RED-S among vegetarians may also be unintentional and due to the selection of low energy-dense, high-fiber plant foods coupled with high training demands (see previous section on Energy). This can result in dampened circulation of sex hormones (including estrogen, progesterone and testosterone) due to the disruption of normal hypothalamic reproductive function from reduced energy availability. The earlier literature has also observed that lower circulating estrogen concentrations in vegetarians compared with non-vegetarian was associated with higher fiber and lower fat intakes, and higher fecal outputs of estrogen (Larson-Meyer, 2018). Lower circulating testosterone in male athletes due to higher fiber or reduced energy intake is also possible. Lower testosterone concentrations, however, are not driven by excess

consumption of soy foods or soy phytoestrogens (Hamilton-Reeves et al., 2010). Soy consumption in male athletes does not lead to feminization in male athletes. Vegetarian athletes with abnormal menstrual function or reduced testosterone should be counseled on how to meet energy needs on a vegetarian diet. For athletes in heavy training, a plant-based diet with excessive fiber may result in insufficient low energy intake and potentially reduce enterohepatic circulation of sex steroid hormones. Female athletes experiencing amenorrhea should be encouraged to see their personal or team physician for a thorough evaluation.

Young Vegetarian Athletes

Vegetarian diets are appropriate for all stages of the lifecycle including childhood and adolescents (Melina et al., 2016). The young athlete, however, may be faced with additional challenges during times of growth combined with excessive training and/or sports participation. Nutrients that may require attention in the planning of nutritionally adequate vegetarian and vegan diets for young athletes, particularly during times of growth, include iron, zinc, vitamin B-12, and for some calcium and vitamin D. In addition, the protein needs of vegan children may be slightly higher than the RDA to account for differences in protein digestibility and amino acid composition (Melina et al., 2016). Although dietary factors may interfere with absorption of iron and zinc, deficiencies of these minerals are not common in vegetarian children living in industrialized countries (Gibson et al., 2014).

PRACTICAL APPLICATIONS

Vegetarian athletes are capable of reaching their needed energy and nutrient intakes with planning (Melina et al., 2016). The athlete should be encouraged to eat a diet that contains a variety of plant foods including whole and enriched grain products, fruits, vegetables, protein-rich plant foods, and (if desired) dairy products and eggs. Professionals and trainers should make efforts to understand the athlete's reasons for being a vegetarian, be sensitive to each individual's needs, and properly educate vegetarian athletes on sources of both macro- and micronutrients mentioned that fit their personal beliefs and values. The professionals need to make sure the athlete is not claiming vegetarianism in order to mask an eating disorder, as this is a serious mental illness that can impair health and athletic performance. Lastly, the athletes should never be told that they have to eat animal products in order to obtain adequate nutrition.

The following are a few tips to give athletes regarding their nutrition:

- Meeting energy requirements is crucial to obtain proper nutrition and optimal performance.
- Carbohydrates are essential for ensuring adequate adaptation to training and maximizing performance during prolonged and repeated high intensity exercise. Athletes should consume between 3-10 g carbohydrate/kg BM/day (and up to 12 g of carbohydrate/kg BM/day for extreme and prolonged training). Carbohydrate sources include grain products, fruits, juices, starchy vegetables, sports supplements (fluid replacement beverages, gels, sports bars) and added sugars.
- Protein requirements vary depending on exercise type and intensity. Excellent vegetarian sources include soy products, beans, lentils, tofu, nuts, seeds and most grains including quinoa (Table 3). Milk, yogurt, Greek yogurt, cottage cheese and eggs are rich sources for vegetarians.
- Dietary fat is essential for absorption of fat-soluble vitamins and essential fatty acids. Fats that emphasize mono- and polyunsaturated fats, such as nuts and seeds, avocados, olives and olive oil, and sesame oil, should be included in the diet. Vegetarian sources of omega-3 fats which include walnuts, flax, chia, camelina and hemp seed, and canola, walnut, flax and hemp oils should also be part of the diet. However, saturated fat and trans fat intake found in full fat dairy products, coconut and many processed foods should be limited.
- Emphasis on the inclusion of foods rich in iron, zinc, calcium, vitamin B-12 and riboflavin is essential (Table 3). While consumption of these nutrients through natural or fortified foods is preferred, these nutrients may occasionally need supplementation (Melina et al., 2016; Thomas et al., 2016). Vitamin D supplementation, in particular, may be required when sunlight exposure is limited. Iodine supplementation may be needed for those living in areas with low levels of iodine in foods or when not using iodized salts (Maughan et al., 2018). General supplementation should be considered for restrictive or low energy-density diets.
- The athlete's reasons for being a vegetarian should be considered and dietary recommendations based on acceptable foods, given the athlete's underlying philosophies on vegetarianism.

CONCLUSIONS

Athletes at all levels of competition can meet their energy and nutrient needs on a vegetarian or vegan diet that contains a variety of foods, including grain products, fruits, vegetables, protein-rich plant foods, and (if desired) dairy products and eggs. Depending upon food preferences, eating patterns and exercise intensity, however, the diet of some athletes may contain suboptimal amounts of certain key nutrients, including total energy, protein, omega-3 fatty acids, calcium, vitamin D, iron, zinc, iodine, riboflavin and vitamin B-12. In such cases, athletes can generally improve nutrient status through careful selection of foods containing the nutrient(s) they lack (Table 3) and a supplemental source when appropriate. Although research strongly suggests that a plant-based diet may offer many health benefits to athletes and nonathletes alike, there is currently little evidence that vegetarian diets per se are better than omnivorous diets for improving athletic training and performance.

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