Vegetarian dietary practices and endurance performance[1,2]

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ABSTRACT Confounding influences of varying fat, protein, and carbohydrate (CHO) levels, training habits, and lifestyle patterns make the interpretation of specific influences of the diet on endurance performance unclear. In general, exhaustion during prolonged, hard endurance exercise is tied to low muscle glycogen stores. Athletes in heavy training are urged to consume 70% of calories as CHO to maximize body CHO stores. A deemphasis in animal products with an emphasis in high-CHO plant foods would facilitate athletes in conforming to nutritional recommendations. Some female athletes may increase their risk of iron deficiency and/or amenorrhea if a restrictive vegetarian diet is adopted. In general, the high-CHO nature of the vegetarian diet can help the endurance athlete in heavy training maximize body glycogen stores and thus the ability to perform. The balanced vegetarian diet provides the athlete with added reduction in coronary risk factors while meeting all known nutritional needs. *Am J Clin Nutr* 1988;48:754–61.

KEY WORDS Vegetarian diet, endurance, carbohydrate, muscle glycogen

"In 1896, the aptly named James Parsley led the Vegetarian Cycling Club to easy victory over two regular clubs. A week later, he won the most prestigious hill-climbing race in England, breaking the hill record by nearly a minute. Other members of the club also turned in remarkable performances. Their competitors were having to eat crow with their beef."

Whorton JC. *Crusaders for Fitness* (1).

Early research

The relationship between vegetarian dietary practices and endurance performance has a long and colorful history. The ancient Greek athletes were heavy meat eaters. Milo of Crotona, the legendary wrestler who was never once brought to his knees over five Olympiads (532–516 BC), supposedly consumed gargantuan amounts of meat (2). The Greek concept of the importance of meat for performance persisted for many centuries.

Whorton (1) summarized the early history and research on this topic. During the mid-1800s, Liebig (3), the preeminent physiological chemist of his time, promoted the concept that energy for all muscular movement was produced by the oxidation of protein. The customary diets of heavy laborers and athletes were found to be high in protein, and this was accepted by nutritionists as a physical necessity. Food intake studies by Atwater (4) on Yale and Harvard rowing teams revealed that the average crew member consumed 150–170 g protein/d with two-thirds coming from animal sources. Although research of the 1850s and 1860s soon showed that Liebig's theory was false and that carbohydrates (CHO) and fatty acids were the major fuels of muscular activity, Liebig's writings had a continuing impact well into the 20th century. Because the typical meatless diet was thought to contain insufficient quantities of protein, vegetarians were theoretically incapable of prolonged exercise.

Undaunted, vegetarians of the mid-to-late 1800s sought to prove through excellence in endurance exercise the superiority of the plant-based diet (1). During the 1890s the London Vegetarian Society formed an athletic and cycling club. As noted in the beginning quote, James Parsley and the other 90 members of the club vindicated their diet, outperforming their carnivorous competitors. American vegetarian cyclists also demonstrated their abilities. Will Brown, who in the 1890s switched to a vegetarian diet for health reasons, went on to thrash all records for the 3218-km bicycle race. Margarita Gast, on a vegetarian diet, established a women's record for 1609 km.

Other vegetarian athletes joined in the foray. Long-distance walking races were also very popular in the 1890s and were regarded then as the ultimate test of endurance (1). In the 1893 race from Berlin to Vienna, the first two competitors to cover the 599-km course were vegetarians. A 100-km race held several years later in Germany also attracted much attention with 11 of the first 14 finishers being vegetarian.

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[2] Reprints not available.

Many other vegetarian athletes performed amazingly well. In 1912 the vegetarian Kolehmainen became one of the first men to complete the marathon under 2:30. Other records were set by vegetarian swimmers, tennis players, and other athletes, including the West Ham Vegetarian Society's undefeated tug-of-war team.

A few simple early studies attempted to measure scientifically the ability of vegetarian athletes. The Belgian researcher Schouteden (5) carried out tests in 1904 on 25 students divided into vegetarian and meat-eating groups. For each he determined the endurance of the forearm muscles by measuring the maximum number of times each subject could lift a weight on a pully by squeezing a handle. The mean number of contractions for vegetarians was 69, for meat eaters 38.

Fisher of Yale University in 1906 reported on his study of Yale athletes trained on a full-flesh diet, athletes who abstained from meat, and sedentary vegetarians (nurses and physicians from the Battle Creek Sanitarium) (6). Each was tested to determine the maximum length of time that the arms could be held out horizontally. The maximum number of deep knee bends and leg raises was also measured. The final tally for all tests was heavily in favor of the vegetarians. In the horizontal armhold test, only 2 of the 15 meat eaters were able to maintain the arm hold > 15 min and none achieved 30 min. Of the vegetarians, however, 22 of 32 exceeded 15 min, 15 broke the 30-min barrier, 9 broke 60 min, and 1 surpassed 3 h.

Few modern studies have directly compared the athletic capabilities of vegetarian vs meat-eating subjects (7, 8). The fact that the vegetarian diet is not a single defined diet, coupled with the confounding influence that training and lifestyle may have, makes definition of specific influences of the diet on physical performance unclear. This was the conclusion of Hanne (7) after a recent investigation of 49 vegetarian athletes and a similar number of nonvegetarian athletes matched for age, sex, body size, and type of athletic activity. No significant differences were found between groups for a variety of physical fitness, anthropometric, and metabolic variables, including aerobic and anaerobic capacity, hand grip and back strength, hemoglobin, total serum protein, and pulmonary function.

Other researchers have focused their efforts on the functional capacities of primitive peoples consuming vegetarian diets. The Tarahumara Indians, a Ute-Aztecan tribe inhabiting the rugged Sierra Madre Occidental Mountains in the northcentral state of Chihuahua, Mexico, renowned for their extraordinary physical fitness and endurance as long-distance runners, were studied extensively (9–13). Unusual stamina characterized the Tarahumara Indians from the earliest recorded descriptions and is best demonstrated in their popular sport called raripuri in which participants race 150–300 km kicking a wooden ball.

Their simple, near-vegetarian diet, composed primarily of corn and beans (90% of total calories), some greens and squash, two or three eggs per week, and small, infrequent servings of meat, fish, poultry, dairy products, and lard, provides them with 75–80% of total calories in the form of CHO. Intakes of all amino acids, minerals, and vitamins exceed or approximate FAO/WHO recommendations (9). Males average 2800 kcal/d, have skinfold measurements 35–50% lower than that of American males, and serum cholesterol values averaging only 3.52 mmol/L (9, 13). Hypertension, obesity, and the usual age rise in serum cholesterol are virtually absent among the Tarahumaras (13). Their antiatherogenic diet appears to be one factor explaining their exceptional ability to engage in endurance exercise. However, many other factors, especially the physical demands of their harsh environment, probably play an equally if not more important role.

Investigation during the latter half of the 20th century has shifted from a direct comparison of vegetarian vs carnivore to measuring the important role of CHO in endurance performance. The superior performance of some of the early vegetarian athletes is probably best explained not only by their motivation to demonstrate excellence but also by their higher CHO intakes.

The important role of carbohydrate in endurance performance

The studies that will be reviewed here emphasize that the high-CHO diet has special advantages for the athlete who engages in long endurance exercise. Several reviews of the importance of CHO in endurance exercise are now available (14–17).

In 1939, Christensen and Hansen (18, 19) performed several investigations which demonstrated the effect of exercise intensity on the choice of fuel by the muscle during exercise. They found that as the intensity of the exercise increased, the relative contribution of CHO as muscular fuel increased.

The development of the biopsy needle by Bergstrom in 1962 allowed researchers to extend Christensen's findings by measuring the actual amount of glycogen in the muscle. A series of experiments by Scandinavian investigators during the late 1960s demonstrated that the ability to exercise at 70–80% of aerobic capacity (VO_2max) was related to the preexercise level of muscle glycogen (20, 21).

Since then many researchers have examined the relationship between exercise and CHO ingestion on muscle glycogen synthesis during a variety of conditions. Important findings include the following:

1) Body glycogen stores play an important role in hard exercise (70–85% VO_2max) that is both prolonged and continuous (running, swimming, cycling) and of an extended intermittent, mixed anaerobic-aerobic nature (soccer, basketball, repeated running intervals).

2) Exhaustion during prolonged, hard exercise is tied to low muscle glycogen levels. Body CHO stores are thus the limiting factor in ability to perform such exercise. This has been repeatedly confirmed in both cycling and treadmill running experiments (22).

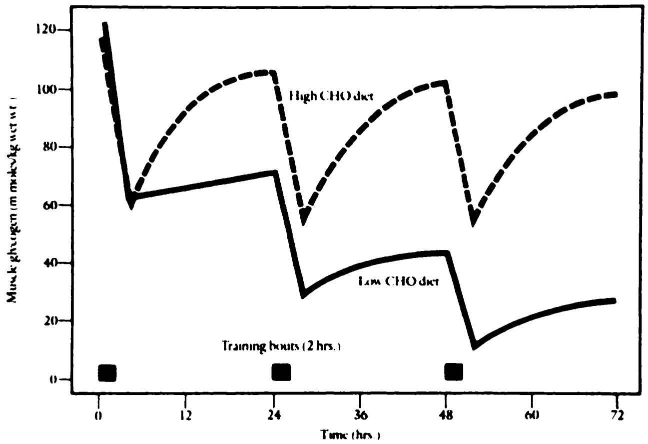

FIG 1. During several days of intense training, a low-carbohydrate diet results in a progressive reduction in muscle glycogen whereas a high-carbohydrate diet helps to keep muscle glycogen stores near normal. From reference 24.

3) When muscle glycogen is low, a high work output cannot be maintained. There is an apparent obligatory requirement of muscle glycogen breakdown for intense exercise. Fat oxidation cannot sustain metabolic rates during exercise of much above 50% VO_2max (23). Thus the higher the intensity of exercise, the greater the demand on body CHO stores.

4) During strenuous training muscle glycogen stores undergo rapid day-to-day fluctuation. Sedentary people on normal mixed diets have glycogen stores of only 80–90 mmol/kg wet muscle (16). Athletes on mixed diets after 24 h of rest have glycogen levels of 130–135 mmol/kg wet muscle; after 48 hours of rest they have 180 mmol/kg. As **Figure 1** shows, these high levels in athletes can be quickly depleted during repeated daily 2-h workouts. However, a high-CHO diet can help counter this glycogen depletion.

5) In general, glycogen synthesis increases in proportion to the amount of consumed CHO. Costill (25) showed that 625 g of diet CHO leads to near maximal replenishment of muscle glycogen after strenuous training. On the basis of these experiments, it is recommended that athletes in heavy training consume a diet of 70% CHO (525 g/3000 kcal). This type of diet will result in a synthesis of 70–80 mmol glycogen/kg wet muscle within 24 h, helping the athlete continue heavy training. Costill (15) reported, however, that this amount of CHO is more than most athletes desire. Therefore they need to be educated to arrange their diets to take in this large amount of CHO. Athletes commonly underestimate their CHO needs and thus become energetically stale from glycogen depletion.

6) Because of limited CHO body stores, the body adapts in various ways to maximize these stores. Endurance training leads to higher stored levels of muscle glycogen, nearly double that of untrained individuals (26). Endurance training also leads to a greater utilization of fat during any given workload, sparing the glycogen (27, 28). Triglyceride stores within the muscle also increase by as much as 83%.

7) During the week before the event, athletes can manipulate rest and diet to cause the muscles to supercompensate with extra high levels of glycogen. Because of the limited stores of CHO in the body, exercise training at 60–80% VO_2max will lead to muscle glycogen depletion after 100–120 min (29). Exercise at 80–95% VO_2max can lead to muscle glycogen depletion even sooner. Various researchers have therefore tried to manipulate muscle glycogen stores with higher-than-normal CHO diets combined with rest to increase glycogen levels above normal in the belief that exercise time to exhaustion could be prolonged. The original Scandinavian researchers set up a regimen now known as the classical method of muscle glycogen supercompensation. In the classical regimen, the muscles are first starved on glycogen by having the subject eat a low-CHO diet for 3 d while engaging in two intense, prolonged exercise sessions. The muscles are then supercompensated with glycogen by resting for 3 d before competition while a 90% CHO diet is eaten. This regimen has been found to create muscle glycogen levels as high as 220 mmol/kg wet muscle (total body CHO stores of 2400 kcal). Unfortunately, several undesirable side effects occur during the depletion phase, including marked physical and mental fatigue, ketosis, hypoglycemia, depression, and irritability (16). During replenishment the athlete often feels heavy and stiff in the legs. Because of these side effects, researchers sought to modify the depletion phase (16). Instead of 3 d of low CHO and hard exercise, the modified scheme utilizes a slow tapering of exercise over a 6-d period. During the first 3 d of this tapering, the diet is a normal mixed diet of 50% CHO calories. During the last 3 d a diet that is 70% CHO is consumed. This modified regimen has been found to create muscle glycogen levels of 205 mmol/kg, nearly the same as the old classical method, without the undesirable depletion side effects.

Nutritional surveys of endurance athletes

Despite the considerable number of publications concerned with nutrition for athletes, very few formal studies of the dietary intake and eating behaviors of athletes have been published. Brotherhood (30) has summarized our present understanding of food intake by athletes. Examination of **Table 1** reveals that there is a wide range of energy intake among athletes. In general, however, athletes tend to be high energy consumers with the size of the participant and the energy demands of the sport having much to do with the number of calories each athlete eats.

As can be seen from Table 1, protein in athletes' diets accounts for ~13–17% of energy intake but the proportions for each individual athlete can vary widely from 10 to 36% (30). Relative to body weight, protein intakes usually exceed 1.5 $g \cdot kg^{-1} \cdot d^{-1}$ and intakes exceeding 2.0 $g \cdot kg^{-1} \cdot d^{-1}$ are common. Although the RDA is only 0.8

TABLE 1
Summary of cross-sectional studies that have evaluated dietary intakes by athletes*

Sport	Daily energy	Protein		Fat		Carbohydrate	
		g	%	g	%	g	%
	kcal						
Aerobic							
Males							
Runners	3000–4000	130	15	145	36	436	49
Cyclists	6300						
Cross-country skier	4700–5500	153	13	215	38	600	49
Females							
Runners	1900–2300	75	15	92	39	240	46
Swimmers	2500–4000	110	13	150	39	400	48
Aerobic-Anaerobic							
Males							
Soccer	3000–5000	140	15	175	40	460	45
Football	2000–11 000	196	16	212	40	539	44
Basketball	2000–9000	180	15	212	41	503	44
Wrestler	1100–6700	95	14	100	32	400	54
Females							
Basketball	1900–3900	108	14	145	40	379	46
Volleyball	1100–3200	103	16	95	34	314	50
Power							
Males							
Track and field	3500–4700	175	17	330	36	470	47
Skill							
Males							
Gymnast	600–4300	77	15	92	40	231	45
Females							
Dancers	900–2900	65	17	65	30	256	53

* Adapted from reference 30.

$g \cdot kg^{-1} \cdot d^{-1}$, athletes do not appear to be much different from the nonathletic population, who tend to consume nearly double the RDA. Fat accounts for ~36% of athletes' energy intakes. This is close to the 39% reported in national diet surveys (31). Again the proportions for athletes vary and range from about 20% to > 50% (30). Power and strength athletes tend to have higher fat intakes than endurance athletes, which is possibly associated with their higher protein intakes as well. CHO provides ~46% (approximately the same as the average American) of the energy consumed by athletes. The range is wide and intakes from 22 to 72% have been reported (30).

There is a paucity of information about the nutritional needs of athletic women involved in endurance sports. Recently, Deuster (32) evaluated the nutritional status of 51 women who had qualified for the First Women's Olympic Marathon Trials. Complete 3-d food records were obtained and blood samples were collected. The percentage of calories was 13, 32, and 55% for protein, fat, and CHO, respectively. Mean caloric intake was 46.3 $kcal \cdot kg^{-1} \cdot d^{-1}$ (range 20.7–84.1) or 2397 kcal/d (range 1067–4271). Mean intakes of most minerals were above RDA. Nutritional supplements were taken by 53% of the women with iron supplements the most common. The National Research Council recommends that women consume 38 kcal/kg. For these active athletes burning at least 800 kcal/d in exercise, 54 kcal/kg is recommended (2600 kcal/d). Over 75% of the women were consuming less than that amount and 25% were consuming < 38 kcal/kg. Eleven percent of the women reported intakes < 1500 kcal/d. Further research is needed to see if training lowers nutrient requirements by enhancing metabolic efficiency.

Another study summarized the dietary intakes of 13 men and 14 women members of the US Nordic Ski team during 1 y of training and competition (33). Four sets of 3-d diet records collected at 3–4 mo intervals showed that the skiers, although consuming high amounts of calories, tended to have a diet similar in composition to the average American diet. Men consumed 3492–5400 kcal/d (49–76 kcal/kg) and women consumed 2414–3963 kcal/d (42–71 kcal/kg) depending on the month studied. All the vitamins and minerals evaluated except for Fe in the females (which was consistently low) were well above RDA. Cholesterol intakes were 655–1210 mg/d for the men and 369–736 mg/d for the women. The researchers concluded that although the total calories seemed adequate to keep these skiers in caloric balance, the absolute caloric intake appeared lower than would be calculated. Apparently some form of metabolic economy must take place in some athletes. In addition, the fat intake was considered too high and the CHO intake too low for optimal performance. Perhaps athletes find it easier to ingest the large amounts of calories they require with high-fat foods, which tend to decrease the absolute size of meals and the fibrous bulk that may cause gastrointestinal discomfort.

These studies and others (34, 35) suggest that most endurance athletes are consuming less than optimal levels of CHO. For athletes in hard training, diets with 70% of the calories in the form of CHO appear necessary to maximize glycogen resynthesis rates.

Various athletes who practice near-vegetarian diets may be able to have better success in adhering to these recommendations. For example, it was reported (36) that Dave Scott, world record holder in the Ironman Triathlon, trains 8 h/d. He fuels himself with a 74% CHO diet of brown rice, tofu, low-fat dairy products, and large quantities of fruits and vegetables, averaging 6240 kcal/d. A recent report (37) on top triathletes found that most were on high-CHO, near-vegetarian diets to support their extremely vigorous training programs. I have measured the diet of the 90-y old vegetarian mountain climber, Hulda Crooks. She trains year-round for her annual climb up Mt Whitney and averages 1700 kcal/d, with 59% of calories from carbohydrate, 25% from fat, and 16% from protein. All major nutrients are at two-thirds RDA or higher. Her training, diet, and lifestyle have contributed to her amazing oxygen uptake capacity, measured at 22.6 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$, equal to that of a woman 30 y her junior. Her body fat is 25.4%, equal to that of a college woman. Further research on the value of very high CHO diets for elite athletes is needed.

Potential problems of the vegan diet with endurance athletes

A wide variety of unrefined plant foods with moderate amounts of dairy products meets all known nutritional needs while helping the individual to conform to what is considered optimal levels of dietary fat and fiber (38, 39). When all animal sources are excluded, more attention should be given to planning a varied, wholesome diet. The greatest risk of the vegan diet comes from undue reliance on a few plant foods. A diet constructed on a variety of plant foods is adequate if vitamin B-12 is supplemented. The less restrictive the vegan diet, the greater the probability that it will meet nutritional requirements, including protein and four potential problem nutrients, zinc, Fe, riboflavin, and calcium.

Athletes who practice vegetarian diets, especially restrictive vegan diets, may be at special risk for potential negative effects, particularly secondary amenorrhea and iron deficiency.

The prevalence of oligomenorrhea and amenorrhea among exercising women is ~20%, although this figure rises among competitive athletes to as high as 50% (40). During studies from a University of Colorado group (41), researchers noted that most female runners with secondary amenorrhea were vegetarians. In their analysis of 11 amenorrheic and 15 regularly menstruating runners, runners with regular menstrual cycles ate five times more meat than the amenorrheic runners. Of the amenorrheic group, nine (82%) were vegetarians (< 200 g meat/wk) whereas only two (13%) of the regularly menstruating runners were vegetarian. Groups were similar in body fat percent, total caloric intake, age at menarche, and weekly training (average of 65.2 km/wk). The researchers reasoned that hormonal precursors and essential minerals such as Zn and Fe could be affected by reduced intake of meat especially in runners.

A report by Slavin (42), however, does not come to the same conclusion. Subjects studied were 36 women cyclists competing in the 1982 Coors Classic bicycle race. Of the 12 amenorrheic cyclers, all reported avoidance of red meat and were consuming modified vegetarian diets. However, 20 of the 24 women with normal menstrual cycles were also ingesting modified vegetarian diets. Hanne (7) reported that when vegetarian female athletes are properly nourished, menstrual cycle function is normal as compared to matched control subjects.

More research in this important area is needed. Female vegetarians were found to have a decreased level of estrogen in their enterohepatic circulation perhaps because of their higher dietary fiber and lower-fat intakes (43). Although the mechanisms inducing athletic amenorrhea have not been determined (44), lower levels of estrogen may be one of several factors (40, 44). As stated previously, several investigations showed that some female distance runners have a caloric intake insufficient to support the amount of training they perform. This energy drain may be a contributing factor in athletic amenorrhea (44). In one study of eight amenorrheic athletes who did not include red meat in their diets, average caloric intake was only 1582 kcal/d and intake of Fe, magnesium, folic acid, riboflavin, and Zn was below two-thirds RDA (45).

Many women lose weight and body fat when they begin regular exercise programs and some acquire very low levels of body fat which may contribute to amenorrhea (40). Vegan endurance athletes in particular may have to be more careful in regards to caloric intake than omnivore endurance athlete. Most studies show that vegans weigh less and have less body fat than omnivores (46–49). Results on lactoovovegetarians are mixed (46, 50–53). Vegetarian athletes need to be conscientious in consuming large amounts of pasta, tubers, dried fruits, brown rice, and other whole grains to obtain sufficient calories while moderating intake of lower-caloric-density foods such as fruits and vegetables.

Several reports in the recent literature suggest that athletes, especially runners, may be prone to Fe deficiency because of increased hemolysis, decreased Fe absorption, and increased Fe loss in sweat, feces, and urine (54–56). Jacobs (57) has described one case of Fe deficiency anemia in a 28-y-old physician who had practiced a strict vegetarian diet for 10 y. Although his diet averaged 17 mg Fe/d, the vigorous exercise training program (145 km/wk) had increased his body Fe loss. Hanne (7), however, reported normal hemoglobin and hematocrits in adequately nourished vegetarian male and female athletes. Sanders (58) concluded that a diet consisting entirely of plant foods is generally adequate to promote normal blood formation provided it is composed of a mixture of unrefined plant foods and is supplemented with vitamin B-12.

Because the vegetarian diet is often less Fe dense than the omnivore diet, the increased Fe requirements of some high-mileage runners may not be met by the vegetarian diet without supplementation. For most vegetarian athletes the including of fortified breakfast cereals, dried fruits, legumes, and tofu in the diet should be adequate. Vitamin C with each meal is recommended to enhance nonheme Fe intake (38). Kelsay (59) has reviewed the literature on dietary fiber and mineral availability. Although dietary fiber can bind minerals such as Fe and Zn in vitro, the high dietary fiber intakes of vegetarians do not appear to be associated with an impaired mineral status. If there is a decreased availability of minerals because of the high-fiber diets of vegetarians, the vegetarians seem to be able to adjust to it. Whether the high-fiber vegetarian diet imposes any special mineral (especially Fe) stresses on the vigorously exercising athlete has not been studied. However, the mineral status of nonvegetarians consuming a vegetarian diet may not be as good as that of vegetarians because of the unaccustomed increase in fiber intake. It may not be wise for a person to adopt a vegetarian diet at the same time a vigorous exercise program is initiated. Research on this matter is needed.

Vegetarians, especially vegans, in addition to weighing less and having less body fat, also have lower blood pressures and more favorable serum lipid and lipoprotein levels than omnivores (60–67). This profile is similar to that of endurance athletes (68–71). Vegetarians were also reported to have lower death rates for cardiovascular disease (72, 73). Thus the vegetarian may be able to engage in endurance exercise more safely and easily than typical US omnivores. On the other hand, vegetarians may experience fewer benefits from endurance exercise than do omnivores. For example, physical activity was assessed in 3933 Californian Seventh-day Adventists in 1960. During 1960–1980, 131 deaths occurred from ischemic heart disease in this group. There was a 2.3 relative risk between groups reporting little and heavy physical labor but it was more pronounced in former smokers and nonvegetarians (DA Snowdon, personal communication).

Researchers (74, 75) recently showed that even athletes in heavy training can experience significant changes in serum cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL-C) when their diets are altered. Lukaski (74) was able to alter the serum cholesterol level from 4.14 to 6.57 mmol/L in cyclers training 483 km/wk by changing the ratio of polyunsaturated fatty acids to saturated fatty acids (P:S ratio) from 2.6 to 0.08. Even athletes in heavy training can benefit from more prudent diet choices.

Although most vegetarians obtain sufficient amounts and quality of amino acids (76–78), athletes consuming restrictive vegetarian diets could be consuming less than optimal amounts of protein. Recent studies (79, 80) indicated that the contribution of protein as an energy source during endurance training is about 5–15%. Various researchers are advising endurance athletes to consume 1.2–1.8 g protein/kg body weight (81, 82). For a 65-kg athlete, this would mean a range of 78–117 g protein/d. If the athlete were to consume 3000 kcal with 15% of calories from protein, 113 g of protein would be ingested. However, on a restrictive vegan diet, this need may not be met.

Conclusion

Although there is little basis for advocating a vegetarian instead of an omnivore diet if CHO intake is constant, the high-CHO nature of a plant-based dietary can facilitate the endurance athlete in consuming 70% of calories in the form of CHO. The well-planned vegetarian diet also provides the athlete with adequate levels of all known nutrients while providing added reduction in cardiovascular disease risk factors. More research is needed to answer some of the questions that have been raised regarding unique risks imposed upon the vegetarian athlete. These include oligomenorrhea and amenorrhea, Fe deficiency, and impaired mineral status from higher-than-normal dietary fiber intakes. The lower protein density of the vegetarian diet is also of potential concern for high-mileage endurance athletes. Research in the future will help to clarify both the benefits and potential risks of the vegetarian diet for the vigorously exercising endurance athlete.

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