Can You Build Muscle on a Plant-Based Diet?

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Introduction

Athletic performance is strongly influenced by diet. Food is often referred to as fuel for the athlete that allows them to train, recover and compete in peak physical condition. Ensuring an athlete consumes sufficient protein, carbohydrates, fat, vitamins and minerals is essential as deficiencies will compromise training adaptations and impair physical performance.

Meat, dairy and eggs are an integral part of the modern athlete's diet, especially when the goal is increased muscle mass and strength. The inclusion of animal foods in the diet reflects the traditional western view of human nutrition where they are considered an essential part of a healthy diet. This view is increasingly being challenged however as plant-based diets move from the fringe to mainstream acceptance. Individuals adopting such a dietary practice typically cite ethical, health or environmental reasons for their choice. Whatever the reason, the growing interest in plant-based diets raises the question for athletes of whether such a dietary practice can support optimum physical performance or will removing animal products from the diet compromise athletic endeavours.

Defining a Plant-Based Diet

There are many variations of plant-based diets. The one thing they have in common is that animal foods are eliminated or minimised while plant foods are maximised.

Table 1. Common plant-based diets

Vegetarian	A diet free of meat but may include dairy and/or eggs
Vegan	Contains no food of animal origin at all
Pescetarian	A vegetarian diet that includes fish but no other meat
Flexitarian	Plant foods form the majority of the diet but small amounts of meat, dairy and eggs may be consumed on occasion

Due to the variety of diets that emphasise plant foods it is not possible to apply a single word that accurately defines them all. The term plant-based diet will therefore be used as a generic description of any diet that minimises or eliminates animal products.

Building Muscle without Meat

Only two studies can be identified in the scientific literature specifically comparing the effects of a meat-free versus omnivorous diet on resistance training adaptations. Haub et al. reported that 12 weeks of resistance training produced similar strength and hypertrophy adaptations regardless of whether the diet contained meat or was meat-free[1]. Campbell et al. reported that a diet containing meat produced greater increases in hypertrophy compared to a meat-free diet during 12 weeks of resistance training[2].

These two studies offer little insight into the significance of plant versus animal protein sources on resistance training adaptations. Regardless of the contradictory findings the diets of the meat-free group still contained dairy and eggs and so do not meet the definition of a plant-based diet. Study participants were all older males, a subgroup that may have impaired protein synthesis[3] which could have influenced the results.

The lack of direct comparative data means it is not possible to conclude with certainty the effectiveness of a plant based diet in supporting resistance training adaptations. In examining this question we therefore need to look at the individual dietary components that support the hypertrophic response to resistance exercise.

Nutritional issues associated with plant-based diets

Protein

Perhaps the most common argument against plant-based diets is the lack of quality protein. This argument has two parts: the quality of plant proteins and the quantity that can be obtained through the diet.

Protein quality is measured via the Protein Digestibility Corrected Amino Acid Score (PDCAAS). This measures how well a protein source delivers essential amino acids to the body. The range is 0-1 with 0 being the poorest quality protein and 1 being the highest quality.

Table 2. PDCAAS for different proteins[4,5,6,7]

Beef	0.92
Milk	1.00
Egg white	1.00
Soy	1.00
Casein	1.00
Whey	1.00
Black Beans	0.75
Peanuts	0.52
Wheat Gluten	0.25
Rolled oats	0.57
Lentils	0.52
Rice	0.44

With the exception of soy protein, plant proteins are less effective at providing essential amino acids in the diet. A limitation in interpreting this data is that the PDCAAS only applies to individual protein sources. Given that a plant-based meal would contain multiple protein sources the PDCAAS of the meal would be higher than the PDCAAS of the individual foods in that meal. This is because the limiting amino acid in one food is complemented by its presence in another food. A classic example is combining beans and rice. Legumes are low in methionine but contain lysine. Rice is low in lysine but contains methionine. Individually they are incomplete proteins due to their limiting amino acids but combining the two foods forms a complete amino acid profile. PDCAAS therefore underestimates the true protein quality of a plant-based meal[4,7].

A balanced plant-based diet containing a wide variety of foods such as whole grains, legumes, nuts, seeds and vegetables provides all the amino acids needed to meet human physiological requirements[8]. Different plant protein sources do not need to be consumed in a single meal but can be spread throughout the day[8]. The quality of protein in a balanced plant-based diet can therefore be equal to that of a diet containing animal protein.

The *International Society of Sports Nutrition* (ISSN) recommends athletes engaged in strength and power exercise consume around 2.0g protein/kg bodyweight[9]. Protein intakes beyond this will unlikely lead to additional gains in strength and hypertrophy[10,11]. Furthermore, the ISSN states that athletes should attempt to obtain their protein requirements from whole foods[9]. A well planned plant-based diet can provide as much protein as an omnivorous diet[12,13] and meet the requirements for the average weight training athlete even without the use of supplements[13].

Fuhrman and Ferreri[13] demonstrate how an 80kg athlete can meet their daily protein requirement from whole plant foods alone. Larger athletes would likely need to use a protein supplement in order to meet their daily requirement. Very large athletes (over 120kg) would struggle to consume sufficient protein on a plant-based diet and so may not be suitable for such individuals.

Iron

Iron deficiency can adversely affect athletic performance by limiting oxygen delivery to cells, resulting in weakness, fatigue, reduced immunity, shortness of breath and heart palpitations[14,15]. Dietary iron comes in two forms: haem and non-haem iron. Foods from animal sources contain both haem and non-haem iron while plant foods contain only non-haem iron. Absorption of haem iron is approximately 15-35% while for non-haem iron it is approximately 10%[16]. A misconception is that meat is the predominate source of iron in the human diet. Historically in western countries less than 20% of dietary iron has come from meat[17,18].

The presence of phytate in many plant foods reduces the bioavailability of non-haem iron. It does this by binding to iron and forming a complex that cannot be absorbed by the body[19]. Legumes contain the highest concentrations of phytate while root and leafy green vegetables and fruit contain very little[19]. Excessive intake of zinc through supplementation may also decrease iron absorption[15]. Non-haem iron absorption is enhanced in the presence of vitamin C however this does not necessarily result in improved iron stores[20].

The human body cannot actively excrete iron. In order to maintain optimum levels the body is able to regulate how much iron is absorbed from the diet. When iron levels are low the body responds by increasing absorption and when iron levels are normal absorption is reduced[21]. As a result athletes on a plant-based diet are at no greater risk for iron deficiency than ominivores[15]. Athletes with diagnosed iron-deficiency anaemia can benefit from iron supplementation[22] but the indiscriminate use of iron supplements in non-diagnosed cases is not warranted and can potentially result in deleterious effects[23].

Vitamin B_{12}

Vitamin B_{12} is needed for blood formation and cell division. A deficiency can lead to macrocytic anaemia and irreversible nerve damage[24]. Early symptoms may include fatigue, appetite loss, digestion problems, nausea, anxiety, mild depression, numbness and tingling in the hands and feet, frequent upper respiratory infections and impaired memory[25]. A B_{12} deficiency will impair physical performance and prevent an athlete from training optimally. Individuals on a plant-based diet are at greater risk of a B_{12} deficiency compared to those that include animal products[26]. This is because B_{12} is the only vitamin synthesised exclusively by bacteria in animals[25].

Dietary sources of vitamin B_{12} are meat, eggs and dairy[27]. Recent evidence[28] suggests the seaweed nori could be a useful plant source of vitamin B_{12}. It is doubtful however that sufficient amounts of nori could be consumed in a western diet, even one that is plant-based, to meet an individual's daily requirements. Bacteria in the small bowel are capable of synthesising B_{12}[29] but there is no evidence they contribute substantially to the needs of the indvidual[25].

Due to the difficulty in obtaining B_{12} on a plant-based diet athletes must ensure they consume foods fortified with this vitamin. A B_{12} supplement is also recommended[30].

Vitamin D

Vitamin D deficiency is a global health problem and is not limited to individuals on a plant-based diet[31]. Globally as many as one in three people may be vitamin D deficient[32]. Vitamin D is critical for proper muscle function, influencing phosphocreatine generation[33], post-exercise recovery[34] and muscle mass[35]. Vitamin D deficiency is associated with greater muscle weakness[36] and increased risk of muscle injury[37]. Athletes who train indoors may be at greater risk of a vitamin D deficiency compared to those who train outdoors[38].

Very few foods naturally contain vitamin D so most dietary sources of this vitamin are fortified foods such as milk[31]. A diet high in oily fish prevents vitamin D deficiency[39] but the major source is exposure to sunlight[31]. Athletes on a plant-based diet who do not regularly consume vitamin D fortified foods and do not get regular sun exposure may be susceptible to developing a deficiency.

Vitamin D is not a single molecule but a group of fat soluble steroid-based molecules. The two most important forms for human health are D_2 and D_3[32]. Of the two D_3 may have the most influence on muscle function[40,41]. Supplementing with vitamin D_2 has been shown to reduce circulating levels of D_3 and significantly increase post-resistance exercise muscle damage[41].

Supplementing with D_3 can improve muscle function and reduce the incidence of injury in active individuals with low vitamin D levels[40]. Indiscriminate vitamin D supplementation on a 'just in case' basis is not justified. Athletes concerned about their vitamin D status should consult a medical practitioner.

Zinc

Zinc is an essential mineral used in enzyme reactions that control gene expression and cellular growth. It is the second most abundant transitional metal in plants, animals and microorganisms after iron[42]. Low intakes of dietary zinc are associated with reduced testosterone levels in otherwise healthy males[43,44].

Individuals who do not consume meat generally have lower intakes of zinc compared to those who do[30]. A balanced plant-based diet can provide zinc at quantities equivalent to an omnivorous diet, however like iron its absorption is hampered by phytate. Plant sources of zinc include legumes, whole grains, nuts and seeds[45]. These foods also contain phytate, making zinc bioavailability on a plant-based diet lower to that of an omnivorous diet[45]. The reduced bioavailability means individuals with high intakes of phytate-rich foods *may* require 50% more zinc than the recommended daily amount[30,45].

There are a number of different strategies athletes can use to enhance zinc absorption from plant foods. Consuming whole foods results in greater zinc absorption compared to refined foods[45]. Phytate levels can be reduced by sprouting grains and legumes prior to consuming[46]. Iron and calcium supplements can decrease zinc absorption[45,46] and so should be used with caution.

Despite the lower absorption of zinc on a plant-based diet there is no clear evidence that individuals following a plant-based diet require zinc supplementation[45]. This may be due in part to compensatory mechanisms that allow the body to adapt to lower intakes[45,47]. If an athlete is concerned about their zinc status it is advisable to consult a medical practitioner.

Given the importance of zinc for testosterone production athletes training for strength and hypertrophy may be tempted to supplement their diet with additional zinc. This is unwarranted for individuals who are consuming the recommended daily intake. Supplementing with additional zinc does not increase testosterone above physiologically normal levels[48].

Creatine

Muscle creatine stores are lower in people following a meat-free diet compared to omnivores[49,50]. Creatine plays an important role in ATP production which provides the energy for muscle contractions. Dietary sources are meat and fish. Creatine is also synthesised in the liver and pancreas from the amino acids arginine, glycine and methionine[51]. Due to its importance in generating the energy for muscle contractions, muscle creatine levels have a strong influence on physical performance[51].

The American College of Sports Medicine states that "exercise performance involving short periods of extremely powerful activity can be enhanced especially during repeated bouts by creatine supplementation"[52]. This statement holds true for both omnivores and athletes on a meat-free diet. Weight training athletes following a plant-based diet who do not currently supplement with creatine may be more responsive to its ergogenic effects in the short term[50]. This is likely attributed to the initial lower muscle creatine levels in those on a meat-free diet. Given the ubiquity of creatine supplementation among weight training athletes it is unlikely that low creatine stores are a significant issue.

Supplements

Protein supplements can play a role in an athlete's diet by contributing to overall daily nutrient intake. The ISSN states that while athletes should attempt to obtain their protein requirements from whole foods supplements do offer a convenient and safe method of ingesting high quality dietary protein[9].

Most of the research into the effects of plant proteins on the hypertrophic response to resistance exercise has focussed on soy protein. Over the short term (training periods up to 12 weeks) soy protein may be as effective as whey protein in supporting training adaptations[53,54]. Over longer periods dairy proteins may lead to greater increases in strength and hypertophy[54-56]. This is because dairy proteins are more likely to be directed towards muscle protein synthesis while soy proteins are more likely to be directed to other parts of the body[54,56].

A 2013 study[57] reported that supplementing with rice protein isolate during an 8 week bodybuilding training program resulted in equivalent gains in strength and hypertrophy compared to supplementing with whey protein isolate.

Hormones

Some individuals may be concerned that a plant-based diet could negatively influence normal hormone production. This concern is unfounded as studies have shown no difference in total or free testosterone between males on vegan diets and those who consume an omnivorous diet[58,59].

Soy can be a valuable source of high quality complete protein for any athlete. Even with a PDCAAS close to or equal to that of animal proteins soy is typically avoided by many athletes for fear its high phytoestrogen content will cause estrogen levels in the body to rise and testosterone levels to fall. This concern is unjustified as moderate consumption of soy is unlikely to result in hormone disruption[60].

Limitations of a plant-based diet

Plant-based diets are generally lower in calories than omnivorous ones[61]. For hard training athletes, especially those training to increase muscle mass and strength, this is a potential problem. Inadequate energy intake leads to increased dietary protein needs[6]. Failure to consume sufficient calories without compensating with additional dietary protein will result in impaired muscle protein synthesis. An energy deficit of 20% has been shown to result in a 60% increase in muscle protein breakdown[62].

Fuhrman and Ferreri[13] demonstrate that it is possible for an athlete to consume upwards of 5000 calories on a plant-based diet focussing on whole foods and without the use of supplements. While this level of energy intake is possible it requires the consumption of a *lot* of food. Individuals working full time, juggling family responsibilities and training regularly would likely struggle to find the time to prepare and eat such large quantities of food. There are no easy answers to this dilemma but including energy dense foods such as nuts and seeds in the diet can help maximise energy intake. Very large athletes trying to increase or even maintain their high level of body mass would likely struggle to consume sufficient calories on a plant-based diet, even with the use of supplements. A plant-based diet may therefore not meet the nutritional needs of these athletes.

Conclusion

The absence of directive comparative data between omnivorous and plant-based diets as part of a structured resistance exercise program means it is not possible to conclude how effective a plant-based diet is at supporting the hypertrophic response. Despite the lack of direct data the evidence shows a well planned and balanced plant-based diet can provide the nutritional foundation to support strength and hypertrophy adaptations. Whether a plant-based diet can support *optimum* training adaptations is another question entirely and one that cannot be answered at this time.

Conflict of interests

The author declares no conflict of interest in the publication of this review.

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