LET THE PLANT-BASED GAMES BEGIN

Optimizing Athletic Performance with Plant-based Nutrition

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A PLANT-BASED DIET IS A DIETARY PATTERN THAT MAXIMIZES PERFORMANCE IN THE NEAR TERM AND ENSURES THE HEALTHIEST FUTURE.

INTRODUCTION
WHY THIS PLAYBOOK?

Scott Stoll, MD, FABPMR, Olympian, 1994

I will never forget the joy of representing my country in the sport of Bobsled at the 1994 Olympics in Lillehammer, Norway, and the flood of emotions that I experienced as I walked into the opening ceremonies. It is one of the greatest honors and memories of my life. Like most athletes, I was intensely focused on optimizing my performance through advanced training methods, diet, and nutritional supplements. But now I recognize that my decisions were largely influenced by fellow athletes, coaches, or popularized science.

Just prior to the Olympics, I was accepted into medical school and granted a deferment to compete in the 1994 Games. Despite my educational background it was the fear of missing out on the latest popular dietary or training innovation, and associated group think, that was more persuasive than a careful review of the scientific literature, or my understanding of physiology. This naturally led to a short-sighted performance paradigm because I didn't appreciate the profound impact of my lifestyle choices on my immediate performance, or my short- and long-term health. For example, a myopic focus on protein caused me to overlook the fact that the package carrying the protein is more important, and either supports or detracts from the homeostatic function of most body systems. Nearly a decade later as a practicing physician in sports and musculoskeletal

Scott ▶

medicine, I had an encounter with a patient that led me down a pathway of scientific exploration that would redirect the course of my career and revolutionize my understanding of disease, health, and human performance. It was a typical busy day in the office with a full training room schedule in the evening at the local university. I hurried into the exam room to find my patient sitting on the exam room table. She greeted me with a laugh, saying: “Dr. Stoll, can you help me? I’m falling apart.”

It was a statement I heard almost every day and believed it was the inevitable consequence of aging and unfortunate genetics. However, sparked by curiosity, I simply asked my patient what falling apart meant to her. After a long pause, and with tears beginning to form in the corners of her eyes, she disclosed that her family finances were falling apart due to the cost of care and her inability to work, she couldn’t travel to see her grandchildren, serve in the community, attend social and religious activities, and her marriage was severely strained due to the stress associated with chronic disease.

Turning her gaze from the floor to my eyes, she asked with guarded hope, “Dr. Stoll, can you help me?” In the uncomfortable silence that followed, I immediately recognized that my training was insufficient to answer her most pressing question and provide her with any meaningful recommendations. I immediately realized that I didn’t understand the root cause of the diseases impacting her quality of life and I couldn’t confidently suggest it was scientifically possible to reverse the course of these diseases and restore her lost quality of life.

The unanswered questions propelled me on a 20-plus year journey of research and scientific discovery into the origins of lifestyle related disease, or non-communicable disease (NCD), and the vast, growing body of scientific evidence for the prevention, suspension, and reversal of these diseases.
The evidence-based answers that I and others have discovered transformed my medical practice. It has opened doors around the world to work with healthcare providers, healthcare systems, and governments to implement lifestyle medicine solutions that effectively normalize physiologic function and reverse the underlying mechanisms of chronic disease.

A parallel body of research is now confirming the molecular, physiologic, and sports science of a plant-powered plate to similarly optimize the complex biologic systems of an athlete, enhancing performance on every level. Principally, a plant-based diet is a dietary pattern that maximizes performance in the near term and ensures the healthiest future. A plant-based diet offers the greatest level of disease prevention, mental health, and well-being.

Why is this important today for athletes of every level, and specifically Olympic athletes and coaching staff?

Described in detail in this document, the scientific evidence supporting a whole-food, plant-based dietary pattern is compelling on numerous fronts:

1. A well-planned, plant-based dietary pattern is nutritionally superior to other dietary patterns based on comparative analyses of fiber and macro-/micronutrient profiles that contribute to optimized physiologic and biochemical function.
2. Enhanced immunity, which is relevant not only during the COVID-19 pandemic, but also critically important for athletes during the season and prior to important events.
3. Supports complex biologic systems, such as the microbiome, angiogenesis, epigenome, endothelial cells, inflammatory pathways, activation of stem cells, mitochondria, hormonal homeostasis, and neuro-cognitive/mood that support energy production, tissue healing, resolution of oxidative stress, brain activity, and disease prevention.
4. Addresses another global pandemic. According to data from the World Health Organization (WHO), non-communicable diseases, like heart disease and diabetes, are responsible for more than 71% of deaths (41 million people annually) and 60% of the global burden of disability. These deaths and disability are largely preventable.

   Olympians are not immune from these statistics, and science reveals that diseases like heart disease, type 2 diabetes, autoimmune diseases, and many cancers begin at a young age. To succeed in the long game of life, it is critical that elite athletes understand how to create a lifetime of healthy, optimized performance.
5. Recent evidence from numerous publications including EAT Lancet, EPIC, and the WHO highlight the critical global impact of industrialized dietary patterns. These dietary patterns affect climate change, food access for more than 2 billion people, and the environmental resources we are stewarding for the next generation. The conclusion of an ever-growing number of studies is that a global shift to a plant-based dietary pattern is the single most important step to address the crisis and create a sustainable future for all.
6. Finally, Olympic athletes personify health in the eyes of the public and therefore have the unique opportunity to influence culture around the world, contributing to a global shift toward a dietary pattern that simultaneously addresses the pandemic of NCDs, climate change, and improves individual health and well-being.

This plant-based playbook represents a summary of the compelling scientific evidence presented by a representative group of leading researchers, athletes, and healthcare professionals. Together they draw upon peer-reviewed evidence from a diversity of scientific fields to illustrate the unique ability of a plant-based dietary lifestyle to optimize the continuum of human and planetary health and performance. Also included is a robust tool kit to aid in the implementation of this dietary pattern and provide support for your team. It is designed with a variety of practical resources necessary for efficiently and safely integrating a plant-based diet into the lives of athletes. Combined, this plant-based playbook is an invitation to discover a dietary lifestyle that provides the greatest opportunity to improve human performance and simultaneously regenerate the health of individuals and the earth we are stewarding for future generations.

THIS PLANT-BASED PLAYBOOK IS AN INVITATION TO DISCOVER A DIETARY LIFESTYLE THAT PROVIDES THE GREATEST OPPORTUNITY TO IMPROVE HUMAN PERFORMANCE.

Rachael Adams, Plant-based Athlete
Olympic Bronze, 2016

SECTION 1

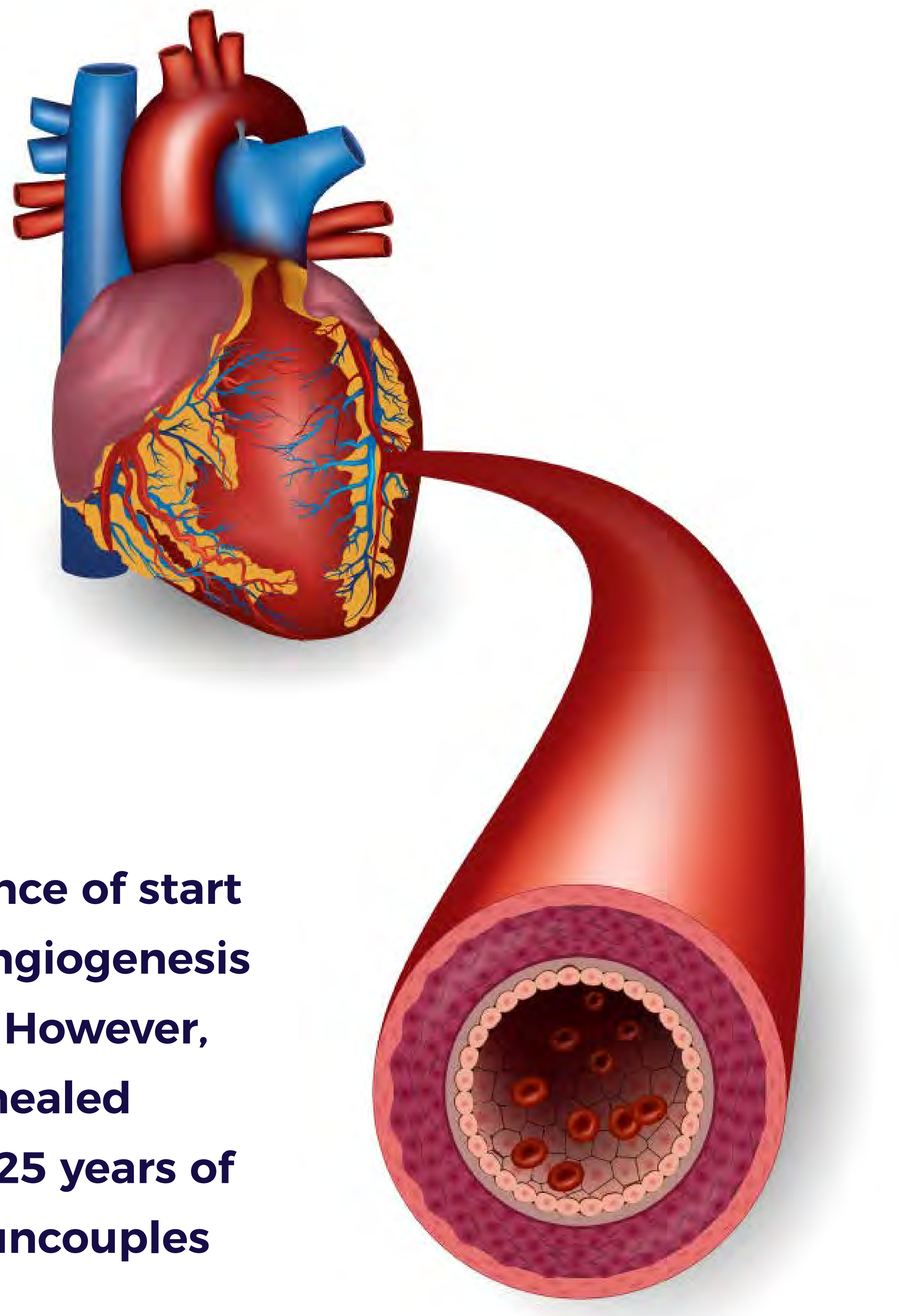
THE POWER OF A PLANT-BASED PLATE TO OPTIMIZE BIOLOGIC SYSTEMS

Scott Stoll, MD, FABPMR, Olympian, 1994

Introduction

Dietary discussions in sport are largely driven by a myopic focus on macronutrients and supplements with a nod toward basic micronutrients. However, sports nutrition science has evolved considerably in the last five years. Now there is a greater understanding of the impact of micronutrients and fiber on key regulatory physiologic "switches" and complex biologic systems. The real-time interactions between the thousands of phytochemicals and fiber, and the biologic systems of the body, dramatically enhance strength, endurance, recovery, and injury prevention. At the same time, they protect the body from common non-communicable diseases like diabetes, heart disease, and cancer.

Optimized performance and health are synergistic goals that can only be achieved through the vehicle of a healthy diet and lifestyle. Turning to the published, evidence-based literature it is possible to see the positive impact of a whole-food, plant-based plate on the function of complex biologic systems that are essential for human performance. Each of the systems briefly summarized below are directly impacted by daily food choices and have the potential to dramatically enhance performance, improve resilience, and protect against disease.

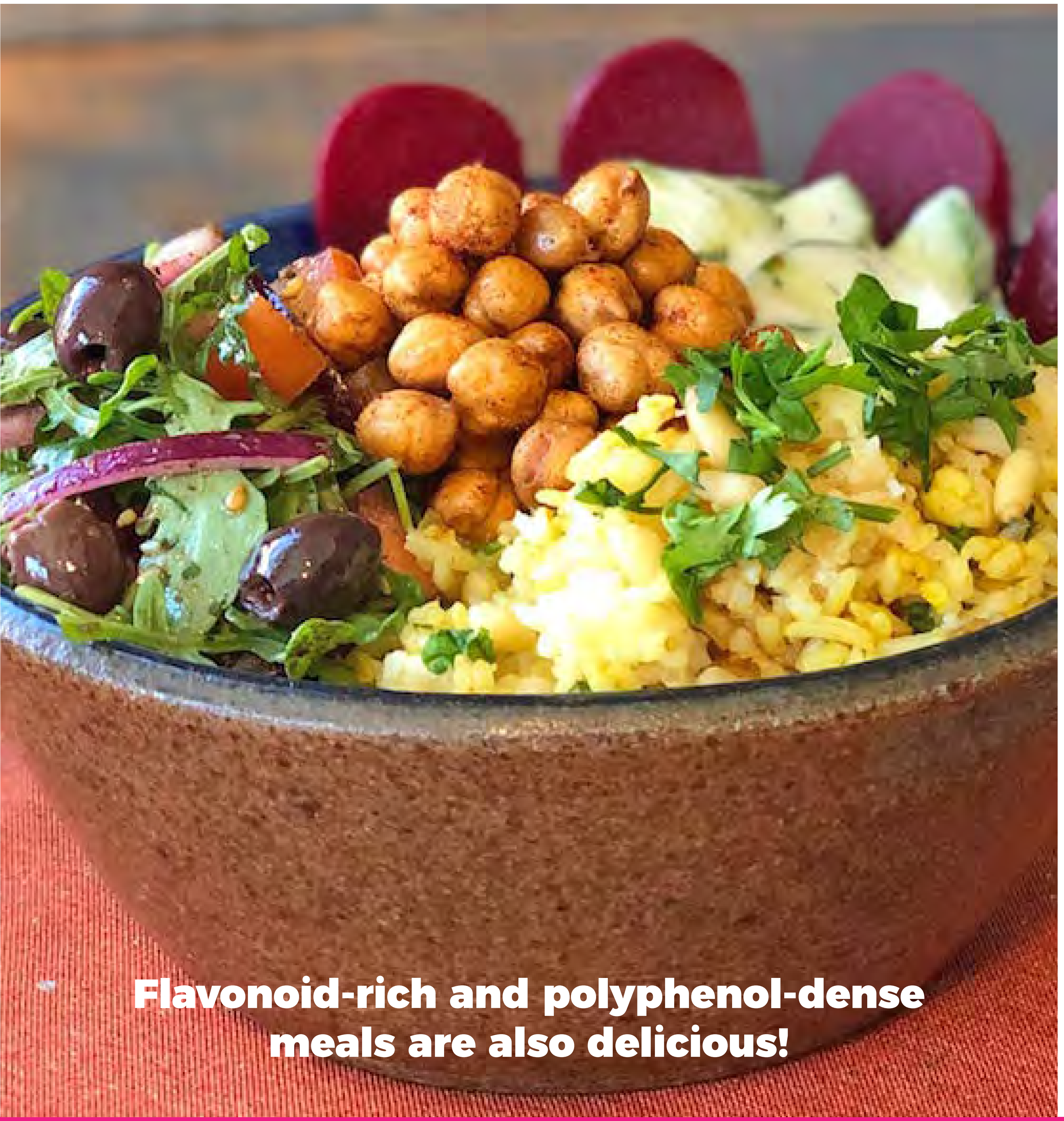


Angiogenesis/Endothelium

More than 60,000 miles of blood vessels serve as the supply chain of the human body, delivering oxygen, raw materials, and removing metabolic by-products. Blood vessels are lined by a single layer of cells called the endothelium. Healthy endothelial cells reduce inflammation, monitor blood flow, prevent clotting, and produce a potent vasodilator: nitric oxide.

Angiogenesis is the normal process of growing new (genesis) blood vessels (angio) that is controlled by a precise balance of start and stop, or pro-angiogenic and anti-angiogenic signals. For example, acute injuries trigger a cascade that activates angiogenesis to grow blood vessels into the area of the torn tissue. Once the injury is repaired, the excess blood vessels are pruned. However, in an unhealthy body, this process is disrupted leading to deficient or excessive blood vessel growth seen in partially healed tissue or the abnormal growth, neovascularization, of cells in conditions like cancer and atherosclerosis.[1,2,3] More than 25 years of research has documented that an industrialized diet high in saturated fat, sugar, refined grains, stress, and inactivity uncouples

THE BIOACTIVE COMPONENTS OF PLANTS SUPPORT THE HEALING OF TISSUE LIKE BONE, MUSCLE AND SKIN, AND ENHANCE BLOOD SUPPLY TO MUSCLE.



Flavonoid-rich and polyphenol-dense meals are also delicious!

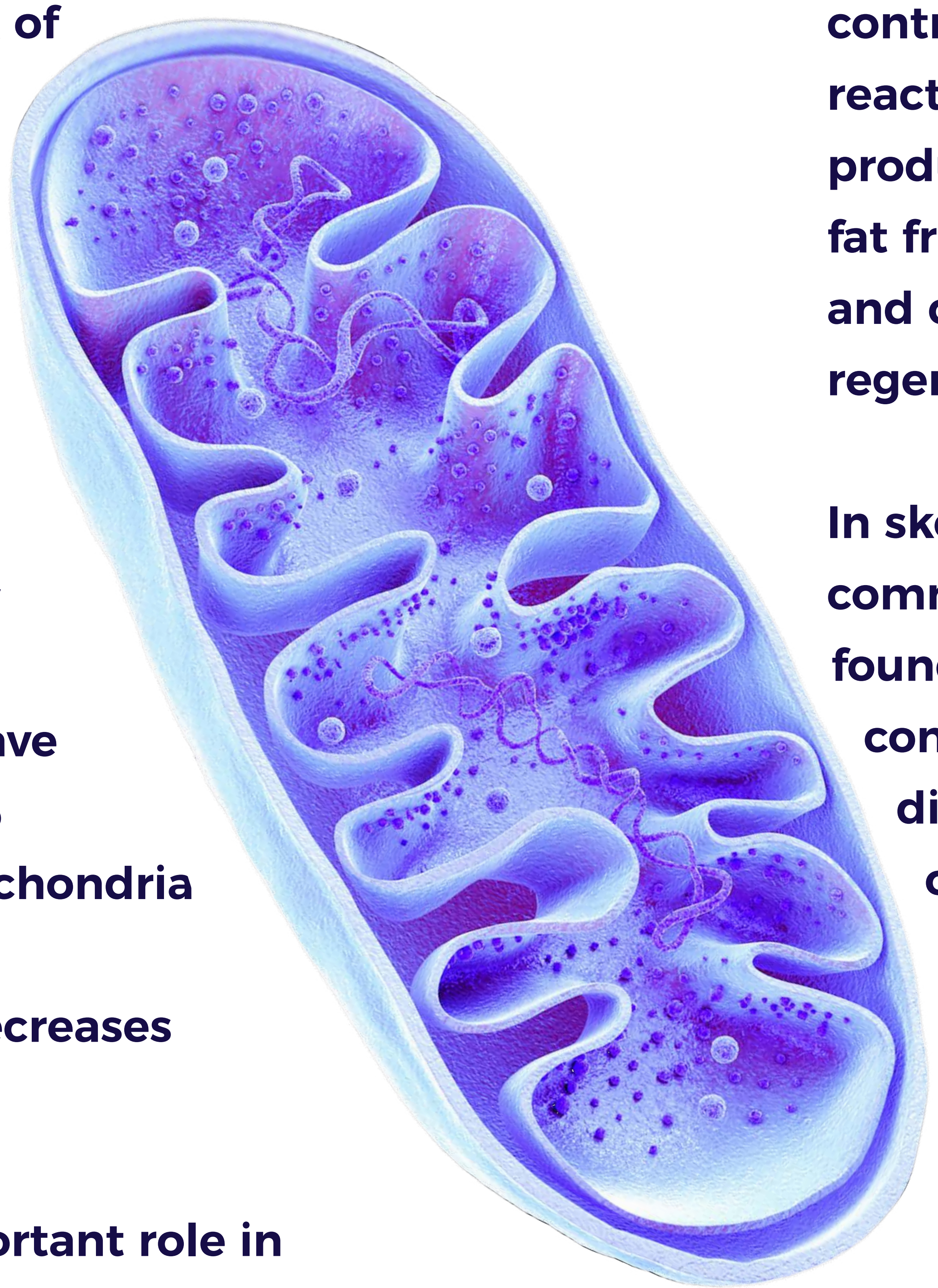
the normal growth/pruning cycle of angiogenesis.[4,5,6] While a diet rich in whole-plant foods, herbs, and spices restores balance and homeostasis to the angiogenesis system.

Sport, especially aerobic sports, requires a complex remodeling of cardio/pulmonary tissue and skeletal muscle to create networks of capillaries to supply oxygen, repair tissue damage, and support new growth. In balanced systems, exercise is pro-angiogenic leading to the development of lung tissue, increased myocardial capillary density, and skeletal muscle regeneration.[7] Over-training is associated with excessive oxidative stress, tissue injury, and dysregulation of angiogenesis that decrease the body's ability to respond adequately to the increased load and demand.[8]

In a 2021 paper, Balberova et al. commented on the importance of angiogenic balance for athletes stating: "Violation of the 'angiogenic switch' as a balance between pro-angiogenic and anti-angiogenic molecules can lead to a decrease in the functional resources of the nervous, musculoskeletal, cardiovascular, and respiratory systems in athletes and, as a consequence, to a decrease in sports performance."[9] New evidence demonstrates the unique ability of vascular endothelial growth factor (VEGF), a key stimulator of blood vessel growth, to induce myofibril regeneration as well as a wide range of cell differentiation in a variety of tissues including skeletal muscle.[10] Athletes that capitalize on the dietary and lifestyle influencers of angiogenesis enhance their body's ability to repair and regenerate, gaining an edge on their competition.

Extensive research has identified the lifestyle and environmental factors involved in the homeostasis of angiogenesis. Fundamentally, healthy dietary patterns are perhaps the most important regulator of the angiogenic switch; precisely modulating between the growth and pruning cycles.[11] A diet rich in plant foods such as dark leafy greens, cruciferous vegetables, soybeans, berries, grapes, garlic, onions, mushrooms, spices, and herbs like turmeric, cinnamon, ginger, and parsley normalize angiogenesis.[12-14]

The bioactive components of plants, like flavonoids and polyphenols, improve the function of the endothelial cells, maximize the release of nitric oxide, support the healing of tissue—like bone, muscle and skin—and enhance blood supply to muscle.[15] Taken together, the angiogenesis research supports the role of a whole-food, plant-based plate to optimize tissue recovery, healing, and the response to training; while at the same time dramatically reducing the risk of future lifestyle-related diseases.



Mitochondria

Classically named the "powerhouse of the cell," mitochondria are recognized as a key organelle in aerobic activities and endurance sports. Optimal mitochondrial function is essential for endurance, recovery, and energy production; any dysfunction contributes to reduced aerobic capacity. Trained athletes have greater numbers of mitochondria, 30%-100% increases in 4-6 weeks of training. More mitochondria means better oxygen usage, which preserves carbohydrate oxidation and glycogen, and decreases lactate production.

Mitochondrial dysfunction also plays an important role in the etiology of numerous diseases including diabetes, cancer, cardiovascular disease, aging, and delayed wound healing.[16] At the core of energy production, mitochondria are a key to human performance and yet the dietary strategies to improve mitochondrial function are infrequently discussed.

The western dietary pattern high in fat and saturated fatty acids contributes to mitochondrial dysfunction and increased production of reactive oxygen species (ROS) that cause damage to cells, reduce energy production, and drive inflammation.[17] Further, diets high in saturated fat from animal products have been shown to increase oxidative stress and contribute to a loss of myelinating cells that are important in nerve regeneration.[18]

In skeletal muscle the free fatty acid profile (palmitic and stearic acid) commonly found in animal products and processed foods has been found to impair mitochondrial function by reducing ATP production and contributing to insulin resistance.[19] When sugar is added to a high-fat diet, mitochondrial function declines more rapidly with higher levels of oxidative stress and a decline in cardiometabolic function.[20] It is well known that high intensity exercise increases oxidative stress and depletes important antioxidant stores like vitamin E and antioxidant systems like glutathione. The ROS produced during exercise are generally beneficial and serve as important signaling molecules. However, the longer-term consequences of elevated levels of ROS, such as mitochondrial DNA damage, tissue damage, and delayed recovery depends on a variety of factors of which diet is perhaps the most important. Without adequate nutrition from a variety of whole plant foods, these important antioxidant systems can't be replenished.

PLANT-BASED FOODS PROVIDE A UNIQUE OPPORTUNITY TO ENHANCE ENDURANCE AND RECOVERY THROUGH THE FORMATION OF NEW MITOCHONDRIA OR MITOCHONDRIAL BIOGENESIS.

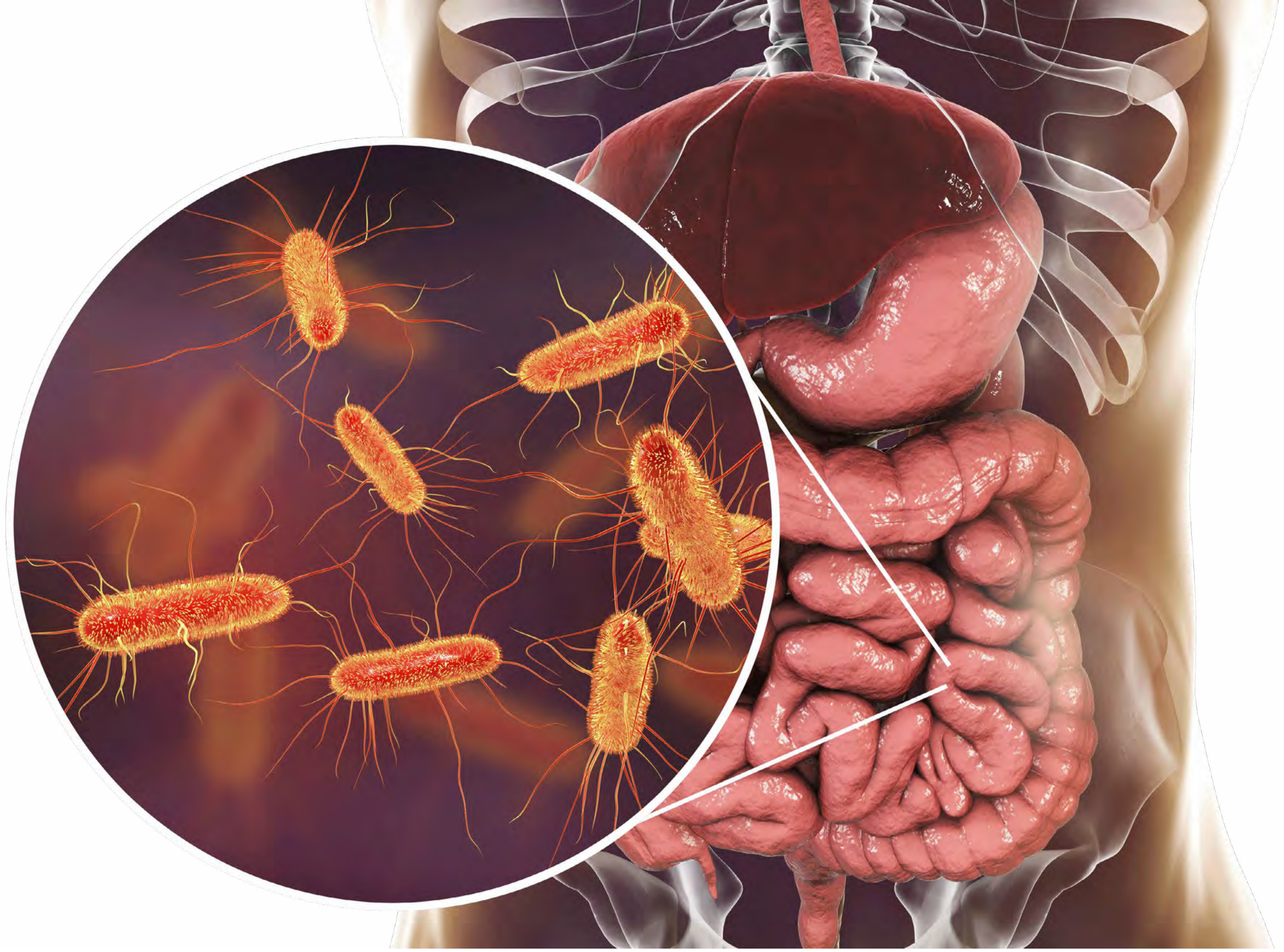
Improved athletic performance relies upon both mitochondrial efficiency and the absolute number of mitochondria. Once again food plays a critical role. Plant-based foods provide a unique opportunity to enhance endurance and recovery through the formation of new mitochondria or mitochondrial biogenesis. The creation of new and more efficient mitochondria is an excellent model to describe the complex interrelated relationship between dietary patterns and the simultaneous, beneficial influence on multiple systems. For example, whole plant foods contain polyphenols and fiber that interact and feed the microbiome that in turn produces molecules that influence mitochondrial efficiency and biogenesis.[21]

In many countries around the world where the industrialized diet has become common, only 5% of people from any age group meet the basic Adequate Intake (AI) of 25-30 grams of fiber per day. Evolving research suggests that the recommended AI is likely only half of what is necessary for optimal health and performance and is associated with the development of non-communicable diseases like coronary artery disease, diabetes, and cancer.[22]

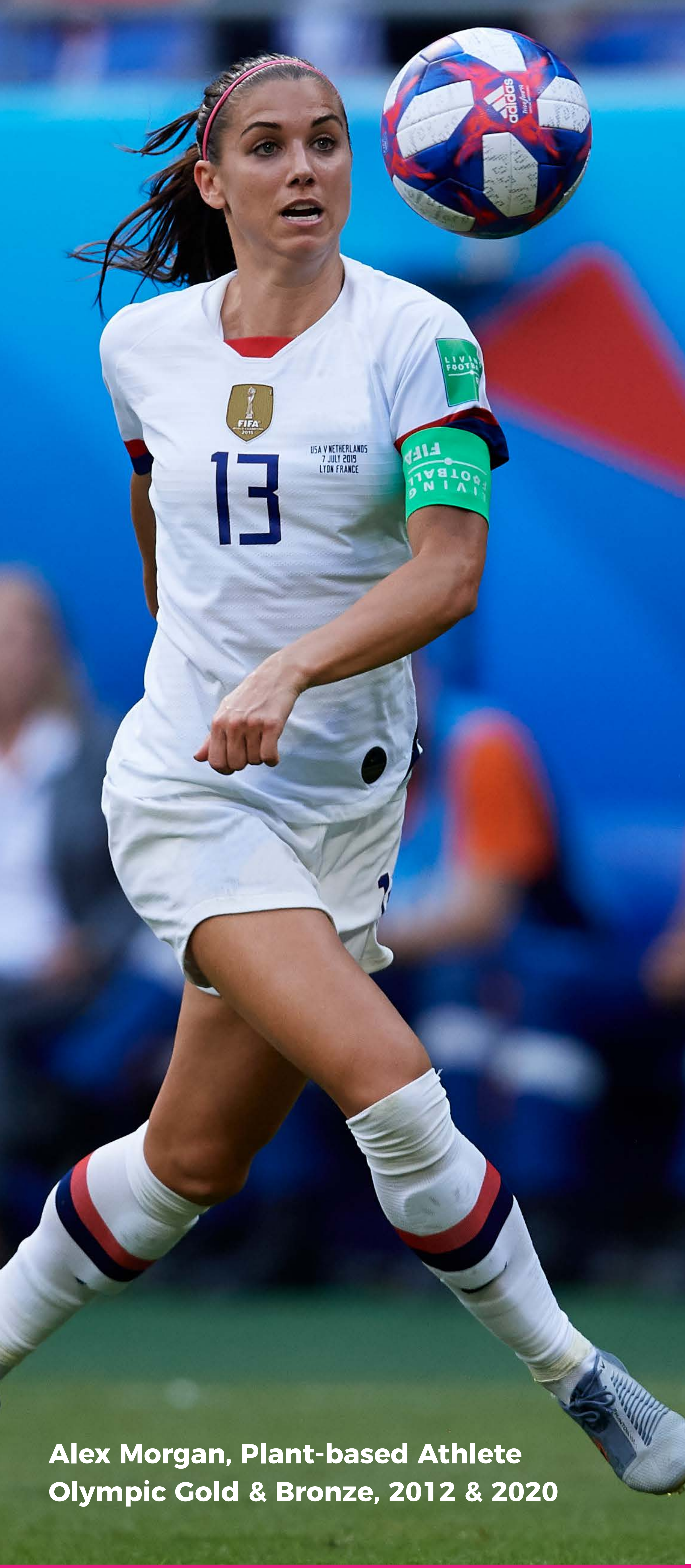
Fiber from plant-based foods not digestible by humans can be digested by the bacteria making up the intestinal microbiome. The bacteria feast on the fiber and produce by-products called short-chain fatty acids (SCFAs) such as butyrate, acetate, and propionate. They act locally in the gut to protect against inflammation and cancer and are absorbed into the bloodstream, stabilize blood sugar, and reduce inflammation by turning off main inflammatory switches, like NF-kB, and activate key epigenetic regulatory switches like PGC-1α. Short-chain fatty acids also embody powerful mitochondrial regulators. Supplementation with butyrate in research studies has been shown to regulate glucose and fatty acid metabolism, increase mitochondrial bioenergetics, and produce more mitochondria, that effectively translates into improved strength and endurance.[23,24] Additionally, butyrate activates the PGC-1α "switch" and sets in motion molecular mechanisms that transform muscle fibers to more type 1, with a higher capacity for oxidative metabolism. This produces increased muscle efficiency and improved energetics that result in improved endurance and recovery.[25]

Similarly, polyphenols—plant compounds rich in antioxidants—found in colorful vegetables and fruits, activate genes that improve mitochondrial efficiency and increase blood vessel dilation to deliver more oxygen. Specifically, polyphenols activate pathways that remove damaged mitochondria and replace them with new synthesized mitochondria.[26,27] They also act as potent antioxidants and help mitigate the oxidative stress associated with high-level training. During an intense training bout, muscle cells require 200 times greater oxygen utilization and subsequently produce large amounts of ROS that can cause damage and inflammation.[28] This unbalanced or excessive ROS, 10-20-fold in high level exercise, induces a pro-inflammatory state that exacerbates muscle and cell damage and can lead to contractile alterations, accelerated fatigue, and longer recovery times.[29] Diets high in polyphenols have been shown to reduce oxidative stress/inflammation, delay fatigue, and enhance the recovery process.[30] Polyphenols, like anthocyanins in apples and curcumin in turmeric among others, also activate the PGC-1α switch leading to mitochondrial biogenesis and enhanced performance.[31,32] Polyphenols also positively impact brain function and in athletes may delay the perception of fatigue, improve mood and cognitive performance, and alleviate depressive symptoms.[33-35]

Homeostatic mechanisms maintain the body's systems and finely tune responses to training. For example, the ROS produced during exercise are important and help drive adaptation and enhanced performance.



Supratherapeutic doses of supplements can adversely impact this balance. Studies utilizing supratherapeutic doses, exceeding the amounts commonly found in food, suggest that it may be detrimental to the adaptation response or negatively impact gene expression.[36] For example one study supplemented Vitamin C and E and found that the supplements dramatically blunted the beneficial effects of exercise including improved insulin sensitivity, mitochondrial biogenesis, and antioxidant activity.[37] The synergistic benefits of a dietary pattern of whole-plant foods cannot be underestimated nor replaced with isolated compounds or supplements.



Alex Morgan, Plant-based Athlete
Olympic Gold & Bronze, 2012 & 2020

Microbiome

The microbiome and its complex interactions and contribution to health, disease, and human performance are the subject of a vast new area of research. It is a primary interface of diet and human health and is in a state of constant adaptation and change related to dietary, lifestyle, psychosocial, and environmental exposures. Research has documented a multitude of microbiome interactions relevant to athletes including the brain (gut-brain axis), immune system, muscle, and mitochondria.

Dietary fiber, found only in plant-based foods, is essential to feed healthy populations of bacteria in the gut microbiota that produce by-products called short-chain fatty acids (SCFAs). Resistant starches found in foods like beans, lentils, and whole grains, support healthy populations of bacteria that produce SCFAs. In addition to the benefits noted in the previous section, SCFAs improve athletic performance by enhancing the bioavailability of glucose, fatty acids, and glycogen during exercise, increasing blood flow, insulin sensitivity, and preserving muscle mass.[38-40]

High-protein, high-fat diets are associated with a lower production of SCFAs, increased gut permeability, and inflammation compared to dietary patterns that are high in fiber (plant-based diets) that increase SCFA production, enhance immune function, reduce gut permeability, and reduce inflammation.[41]

Elite athletes have a greater diversity of bacterial populations that are preferentially equipped to enhance carbohydrate/fiber metabolism and production of amino acids. Moderate physical exercise is associated with beneficial changes in the microbiome. However, intense exercise and overtraining causes hypoperfusion of the gut and increased cortisol production. This contributes to a breakdown in the protective gastrointestinal cell barrier leading to leaky gut syndrome and increased local and systemic inflammation. Research suggests a dynamic, interdependent relationship between exercise, diet, the epithelial barrier of the gut intestinal lining, and diversity of bacteria; resulting in an overall impact on health and performance.[42]

Short-term dietary interventions comparing animal-based diets and plant-based diets identified measurable and significant changes in the populations of bacteria in just 24-48 hours.[43] In one week, a plant-based diet improved the diversity of microbiota, reduced the production of inflammatory molecules like trimethylamine N-oxide (TMAO), and increased the production of butyrate.[44] Animal-based diets increase the abundance and activity of bacteria like Bilophila wadsworthia that support a link between dietary fat, bile acids, and inflammation and diseases like inflammatory bowel disease.[45]

High-protein diets, common in many elite athletes, can result in the production of hydrogen sulfide in the large intestine. High levels of hydrogen sulfide decrease production of butyrate in the gut, disrupt the respiratory chain in the mitochondria shifting it towards glycolysis with increased lactate and decreased ATP production, and increase inflammatory mediators like IL-6.[46] In contrast, plant-based diets favor populations of bacteria like Rosburia that produce important SCFAs, like butyrate, propionate, and acetate; these optimize and protect mitochondria.

IN ONE WEEK, A PLANT-BASED DIET IMPROVED THE DIVERSITY OF THE MICROBIOTA, REDUCED THE PRODUCTION OF INFLAMMATORY MOLECULES LIKE TMAO, AND INCREASED THE PRODUCTION OF BUTYRATE.

Exercise enhances the diversity of the microbiome with greater representation of bacteria, like *Akkermansia*, that produce supportive SCFAs. Although the research highlights an overall beneficial impact of exercise on the microbiome, intense exercise can be detrimental if it is not supported by rest, nutrition, and adequate antioxidant status.[47] Overtraining while consuming a westernized diet produces a pattern of bacterial populations that are more likely to produce inflammatory mediators like lipopolysaccharide (LPS). LPS is a bacterial toxin produced by an unhealthy microbiome and found in animal products. It causes systemic inflammation by activating key switches like NF-kB and AP-1.[48]

In one study examining long distance triathletes, they found microbiota changes after the event with increased LPS levels that were associated with muscle damage and familiar gastrointestinal complaints common in endurance athletes.[49] Multiple studies have documented elevated LPS levels and inflammation markers within 5 hours of an intense exercise bout. Similarly elevated levels of LPS have been found in athletes with higher consumption of saturated fat found in animal products.[50-52]

The systemic inflammation caused by LPS can cross the blood-brain barrier and contribute to neuroinflammation. In a randomized, double-blind placebo-controlled trial, elevated levels of LPS in subjects resulted in elevated inflammatory markers and concurrent mood changes that included sadness, delayed word response, and social disconnectedness.[53] LPS produced by pathogenic bacteria in the microbiota can also disrupt

mitochondrial function increasing the production of inflammatory ROS and release metabolites that decrease energy production via the electron transport chain.[54]

Plant-based dietary patterns are associated with lower LPS burdens and overall improved mental health.[55] One possible mechanism is the improved diversity with healthy populations of bacteria, like Roseburia, that produce butyrate which acts to inhibit the production of LPS and lower inflammation.[56] Consuming a variety of plant-based foods and fiber plays an incredibly important role in the diversity and overall health of the microbiome and gut lining.[57]

Musculoskeletal System

Plant-based dietary patterns may also confer injury prevention and a healing advantage for athletes. In addition to the direct link to chronic disease, researchers are beginning to recognize that a westernized dietary pattern is detrimental to the maintenance and recovery of the musculoskeletal system. Diets high in fat, saturated fat, and processed meat are associated with elevated levels of inflammation, C-reactive protein (CRP), and inflammatory markers like IL-6. While plant-based diets demonstrate lower levels of inflammation.[58,59] Systemic inflammation has been linked to an increased risk for a host of acute and chronic diseases. Many athletes don't recognize the immediate impact of the western dietary pattern, high saturated fatty acids and sugar, and its contribution to cartilage degeneration and a loss of collagen elasticity.[60,61]

Additionally, increased sugar intake and the resultant elevated blood glucose levels, commonly found in the western diet and in the diet of many athletes, increases the production of ROS contributing to cartilage damage and advanced glycation end products (proteins or lipids that are glycated by sugar).[60] Essentially, a western dietary pattern high in saturated fat stimulates chondrocytes to express pro-inflammatory and degenerative proteins, leading to the degradation of cartilage.[62]

Lipopolysaccharide, a bacterial toxin produced by an unhealthy microbiome and found in animal products, can cause systemic inflammation by activating key inflammatory switches, like NF-kB and AP-1 involved in cartilage injury; this can be directly correlated to western dietary patterns.[63] LPS is associated with increased joint pain and inflammation of cartilage. A shift in the microbiota towards unhealthy populations of bacteria like Streptococcus spp. is associated with increased joint pain.[64]

A healthy microbiota supports the musculoskeletal system and preserves cartilage. Plant-based diets high in omega-3 fatty acids and unsaturated fat produce favorable microbiota changes resulting in populations of bacteria that promote butyrate. Butyrate modulates inflammation in the chondrocytes and prevents the degradation of cartilage.[65] In a study of bodybuilders, dietary fiber and adequate protein intake improved microbial diversity and lowered inflammation compared to diets with lower intakes of fiber or protein, while probiotics added no benefit.

The gut-joint axis is further solidified by the presence of gut bacteria in cartilage. Patients with osteoarthritis and cartilage degeneration had different populations of bacteria compared to healthy controls.[66] Emerging research found subchondral populations of bacteria that enhance and protect or degrade cartilage. In early injuries, the osteochondral plate angiogenesis provides an opportunity for gut microbiota to migrate from the gut and populate the area. Unhealthy gut microbiota can lead to a focal dysbiosis in the cartilage with resultant low-grade inflammation, cartilage degradation, and adverse epigenetic changes in chondrocytes.[66] A healthier gut microbiota alters the populations in cartilage and assists in the healing process.

Plant-based diets reduce inflammation and oxidative stress protecting the musculoskeletal system.[67] A wide variety of phytochemicals in plants like anthocyanins in berries, sulforaphanes in broccoli, and curcumin in turmeric inhibit overactive metalloproteinases implicated in the progression of osteoarthritis and reciprocally stimulate chondrocytes to repair and maintain cartilage.[68,69] They also reduce oxidative stress and inflammation and down-regulate pathways associated with muscle degradation and atrophy.

One category of phytochemicals—polyphenols—have a powerful regenerative effect on the musculoskeletal system. They increase the activity of telomerase, lengthening telomeres while also activating the formation of new cells in muscle (myogenesis) bone (osteogenesis), and the brain (neurogenesis).[70-73] Dietary amounts of broccoli and other fruits have been shown to activate mesenchymal stem cells (MSC) and myoblasts leading to protein synthesis and myogenesis.[74] It is clear that the breakfast, lunch, and dinner plate is an important and often underappreciated component of a training plan that can protect and regenerate the musculoskeletal system.


Chase Utley, Plant-based Athlete
MLB World Series, 2008

SECTION 2
PLANT-BASED AND VEGAN DIETS IN EXERCISE AND SPORT

Nanci S. Guest, PhD, RD, CSCS

Introduction

Interest in the benefits of a plant-based diet has risen sharply in recent years. Accordingly, it is important to examine the impact of plant-based diets on physical health, exercise capacity, and performance outcomes in athletes and active individuals. Athletes' dietary patterns range substantially in the degree of inclusion of animal-sourced foods (ASF), from high intake to the complete avoidance of foods or food ingredients of animal origin. With many athletes making the switch to a plant-based diet, it is relevant to consider whether replacing most or all animal proteins with plant proteins will impact exercise and sports performance, or alter an individual's ability to effectively achieve their body composition goals.

Under the umbrella of "plant-based," vegans and vegetarians share a disavowal of meat or animal flesh consumption, but differ regarding the use of foods created by animals (e.g., eggs, dairy) and animal by-products (e.g., casein). The term plant-based is sometimes used interchangeably with vegan to describe a dietary pattern that is 100% plant-based or exclusively derived from plants.[1] However, most individuals appear to understand the term plant-based as being more like vegetarian, i.e., consuming "mostly" plants; however, some diets may still include dairy, eggs, or other ASF and ingredients. This review will use the term plant-based to indicate that the diet is based on "all" or "almost all" plants. The use of this definition implies that a serving of milk, cheese, eggs, fish or foods containing animal-derived ingredients are consumed never or rarely, i.e., no more than 1-2 times per week.

Generally, the term plant-based (PB) is reserved for describing one's diet, and does not necessarily consider or address other lifestyle factors implicated in the use of animals for non-dietary purposes (e.g., clothing). In comparison, the term vegan, or veganism, is more precisely characterized as a justice movement and cruelty-free lifestyle that not only includes a strictly PB diet but also condemns the exploitation and use of animals in any form (e.g., for use as food, clothing, cosmetics testing, experimentation, sport, or entertainment). Accordingly, all vegans consume a PB diet, but not all PB eaters are vegan.

Kara Lang Romero, Plant-based Athlete
Olympian, 2008

Practical Implications

- Whole-food, plant-based diets are increasing in popularity as mounting evidence suggests that they decrease the risk of cardiovascular diseases, diabetes, cancer, and all-cause mortality while also promoting a healthier environment and contributing to climate action.

- Motivations for following a plant-based diet may include improving physical health, reducing the environmental impact of food choices, animal rights/ethics, and athletes optimizing body composition for exercise and sports performance.

- High intake of plant foods has been shown to positively impact many systems in the human body. This includes blood vessel flexibility, oxygen transport to muscles, lower inflammation, quicker recovery from intense training, and increased diversity of the microbiome, which may translate to improved health and performance.

- Most studies show that in general plant-based eating patterns neither improve or hinder physical performance or resistance-training goals. This makes it a viable option for athletes and may also bring comfort to those committed to a vegan lifestyle for ethical reasons.

- Animal protein is not required to build and repair muscle since well-balanced plant-protein meals can provide an excess of essential amino acids with sufficient bioavailability.

- As with omnivorous diets, there are certain nutrients which athletes following a plant-based diet should be mindful to consume in appropriate quantities.

- Although vitamin B12 is the only nutrient that cannot be sourced from plants, nutrients to consider when eating mostly or exclusively plant-based foods also include protein, omega-3 fats, iron, zinc, calcium, iodine, and vitamin D.

- Select ergogenic aids (creatine, carnosine [via beta-alanine]) used for training and performance enhancement are insufficient through food sources and for effectiveness must be ingested in supplement form by both omnivorous and plant-based athletes.

- Athletes who decide to transition to a plant-based diet can feel confident that they will typically see an improvement in their overall nutrition due to increased intake of fruits, vegetables, beans, nuts, seeds, and whole grains. These provide high levels of vitamins, minerals, antioxidants, and fiber, while also being very low in saturated fat.

There is a new vegan-inspired trend surfacing on social and popular media in describing these cruelty-free diets, which is termed animal-free. An animal-free diet excludes any material of animal origin, but can be differentiated from a PB diet by the inclusion of edible fungi such as mushrooms, molds, and yeast from the fungi kingdom. Fungi are neither plants nor animals and they can be consumed ethically in addition to plants as part of a vegan or animal-free diet. There has been a surge in interest around the development of fungal-derived alternative proteins (e.g., mycoprotein) due to their versatility, decreased ethical and resource-use concerns during production, and their many nutritional benefits including a complete amino acid profile.[2,3]

IN ESSENCE, A PB DIET NEED NOT BE SUPERIOR TO ONE INCLUDING ASF, BUT IT MUST BE "EQUIVALENT TO" IN ITS ABILITY TO SUPPORT HEALTH AND ATHLETIC PURSUITS.

Factors contributing to the rise in popularity of PB diets include 1) health benefits associated with increased intake of plant-sourced proteins, 2) concerns regarding adverse health effects of consuming diets high in animal protein (e.g., increased saturated fat), 3) the impact of livestock agriculture on climate change and the environment, and 4) ethical issues regarding the treatment of animals, including concerns for habitat and biodiversity loss, and the increased risk of future pandemics through high-density livestock operations.[4,5]

However, for many athletes, the question is "At what degree of restriction of animal foods will I see a performance benefit?" Perhaps a more appropriate question to ask is "Can a plant-centered diet adequately serve my health, body composition, and performance goals?" That is, can an athlete or highly active individual adopt a strictly PB diet and still expect to perform optimally?

The sporting community's beliefs and attitudes surrounding the need for animal-derived proteins face a conceptual paradigm shift: if we are strictly basing the efficacy of nutritional strategies on performance outcomes, we must accept the viability of evidence-based alternative dietary patterns. In essence, a PB diet need not be superior to one including ASF, but it must be "equivalent to" in its ability to support optimal health and pursuits of athletic excellence. Thus, we must provide the evidence to show that PB dietary patterns can qualify as an acceptable and viable option for the unique nutritional demands of high-performance athletes.

This narrative review will outline the nutrients that may need more consideration when adopting a PB dietary pattern, how PB eating may impact exercise performance and recovery, and address concerns related to the appropriateness of plant proteins for hypertrophy and strength goals. Also discussed are potential issues surrounding the adequacy and bioavailability of plant-sourced micronutrients and the need for nutritional supplements for general health or performance-enhancement.

Plant-based Diets, Health, and Performance

The accumulating evidence on the health benefits of PB diets has made them of interest to consumers, healthcare professionals, and researchers. Among Western populations, PB diets are being adopted to optimize health and lower the risk of many chronic diseases.[6,7] Although there is significant heterogeneity in the types and specific definitions of PB diets and their health impacts, the focus on a healthy, nutrient-rich, plant-predominant diet, whether or not it completely excludes all animal products, has been significantly associated with beneficial health changes.

Positive health outcomes of a PB diet mainly impact cardiometabolic cardiovascular disease (CVD) risk factors through lower body mass indices (BMIs), improved blood glucose and lipid profiles, lowered inflammation and blood pressure.[1,4,7-12] Positive health outcomes also include a reduced risk of several cancers[13-15] compared to most omnivorous diets, which are typically animal-heavy and lower in whole grains, vegetables, fruits, nuts, seeds, and legumes.[16]

IMPROVED METABOLIC HEALTH AND EXERCISE PERFORMANCE IN ATHLETES IS ASSOCIATED WITH INCREASED GUT MICROBIOTA AND DIVERSITY OF SPECIES, WHICH FURTHER SUPPORTS THE HIGH INTAKE OF WHOLE-PLANT FOODS AS A MAJOR CONTRIBUTING FACTOR TO GUT HEALTH AND POTENTIALLY IMPROVED PERFORMANCE.

Habitual dietary intake also profoundly shapes the human microbiome, which is not a fixed trait but instead a malleable part of human health that responds to environmental stimuli such as nutrition and exercise.[17,18] The gut microbiota plays a pivotal role in the regulation of metabolic, endocrine functions, immune functions, and the gut-brain axis.[18] The benefits of plant-derived nutrition on the composition and diversity of the human gut microbiota have been noted after adopting a PB diet.[19,20] For example, many plants contain "prebiotics", which are nondigestible dietary plant fibers that stimulate the growth of beneficial gut bacteria and confer a health benefit upon the host (person).[21] Concentrated food sources of prebiotics include pulses, artichokes, whole grains, bananas, peas, beans, asparagus, and garlic, leeks, and onions.[21]

The main health-promoting effects of the gut microbiota are derived from the production and action of short-chain fatty acids (SCFAs) produced through fermentation of plant and fungi-derived fiber. SCFAs, namely acetate, propionate, and butyrate act as endogenous signals to guide important physiological roles in lipid homeostasis, immunoregulation, maintenance of tissue-barrier function (intestinal wall integrity) and regulation of systemic levels of inflammation.[22,23] SCFAs may also be involved in neuro-immuno-endocrine regulation which may have effects on stress, mood, and sleep.[24]

Improved metabolic health and benefits to exercise performance have been associated with increased gut microbiota and diversity of species[17], which further supports high intake of whole-plant foods as a major contributing factor to an athlete's gut health and potentially to their improved performance.[18] In contrast, excess protein intake may lead to higher levels of proteolytic metabolite production (e.g., ammonia) which may overwhelm the detoxification abilities of the host. This can increase the risk of adverse effects on intestinal barrier function, inflammation, and gastrointestinal health.[25,26] For example, the SCFA butyrate exerts important actions related to cellular homeostasis. Intervention studies have demonstrated that high-animal protein diets reduce fecal butyrate concentrations (and butyrate-producing bacteria) which is likely to be detrimental to colonic health.[27]

Notably, high animal-protein intake (typical in strength and power-oriented athletes) without the concurrent intake of plant-derived dietary fiber, may offset the positive effect of training and exercise on gut microbiota. This can significantly lower the relative abundance and diversity of beneficial bacteria[28,29] which in turn may increase the risk of gastrointestinal distress and inflammation.[18] Gastrointestinal distress in athletes is common and often impairs the ability to adequately fuel or subsequently recover by impeding nutrient digestion and absorption, as well as fluid and mineral reabsorption in the colon.[30] Prioritizing the health of the gut microbiome through whole-food, plant-based diets may offer several advantages for high-intensity training athletes to improve and manage metabolic, immune, and gastrointestinal disorders.[31,32]

Potential mechanisms linking a diet high in PB foods to improved athletic performance are limited but not absent.[33-35] Importantly, many reports show that PB eating patterns neither improve or hinder physical performance[36-38] or resistance training goals[39], which may bring comfort to those committed to a PB/vegan lifestyle for reasons beyond personal gain. For example, a review of eight studies investigating PB and omnivorous diets reported no acute differences between the diets when measuring muscular power, muscular strength, anaerobic or aerobic performance.[36] Similarly, other studies suggest that PB diets do not compromise endurance performance[40] and may even facilitate aerobic capacity improvements in athletes.[41]

Another investigation comparing young athletes who were either omnivores or had been vegetarian (composed of both lacto-ovo-vegetarians and vegans) for at least 2 years, reported higher VO2 max levels in female vegetarians and no differences in the male vegetarian group when compared with omnivores.[41] In the same study, strength (leg extension peak torque) was comparable between vegetarians and omnivores in both men and women, reinforcing the notion that training and performance goals can be pursued by individuals choosing to exclude ASF.[41]

Similarly, a study investigating potential differences in endurance and muscle strength between vegan and omnivore participants reported that both groups were comparable for their typical physical activity levels, BMI, body fat %, lean body mass (LBM), and muscle strength.[42] Vegans

THOUSANDS OF DIETARY PHYTOCHEMICALS FOUND IN, FOR EXAMPLE, FRUITS, VEGETABLES, NUTS AND SEEDS (AND THEIR OILS), LEGUMES, AND GRAINS POSSESS ANTIOXIDANT AND ANTI-INFLAMMATORY PROPERTIES.

in the study had a significantly higher estimated VO2 and submaximal endurance time-to-exhaustion versus omnivores.[42]

More recently, training outcomes and blood biochemical indices were examined in male and female CrossFit participants who followed either a vegan or mixed diet during 4-weeks of high-intensity functional training.[38] Although both groups improved in some but not all exercises, importantly there was no clinically significant difference in performance between diet groups. Based on the findings, the authors also concluded that a properly planned vegan diet does not adversely affect the hematological potential, nor does it affect the lipid profile or markers of liver activity, iron metabolism, and nutritional status, or concentrations of glucose, urea, and creatinine.[38]

As discussed in detail in the following sections, it also appears that muscle and strength development using resistance-type training combined with plant-sourced proteins results in similar outcomes as those seen when using animal-derived proteins,[43-47] particularly when protein ingestion rates are reaching ~1.6 g/kg/day.[46]

To date, as described above, there is no consistency in the data to show that all other factors being equal; one can expect an improvement in athletic performance due to switching to a PB diet. However, the speculation that diets high in plant-derived foods may offer performance benefits appears to have some merit and plausibility on several fronts.[34] For example, studies of individuals consuming omnivorous, compared to PB/vegan, dietary patterns have consistently reported that PB diets are associated with lower BMIs and body fat levels.[48,49] These findings are likely due to the higher fiber content and lower caloric density of PB diets, which may help to optimize body composition, a key performance goal in fitness and sport.[50]

There is also a preponderance of evidence to show that dietary strategies that achieve high carbohydrate (CHO) availability (i.e., to support energy expenditure) are associated with enhanced exercise capacity and sports performance, especially in high-intensity endurance activities.[51] High CHO availability (from plant-sourced foods) prior to and during exercise enhances CHO (glycogen) storage and utilization. These are characteristics that are deemed beneficial to performance, as CHO oxidation produces more adenosine triphosphate (ATP) per unit of oxygen when compared to fat oxidation.[52] High CHO PB diets also foster effective maintenance of glycogen levels, which provide the fuel substrate to support ongoing high-intensity training, sports performance, and recovery efforts.[53] In addition, phytochemical and nitrate-rich PB diets have been shown to increase nitric oxide production (increasing vasodilation), reduce blood viscosity and improve vascular flexibility and endothelial function.[34,54] These actions improve blood flow and oxygenation in skeletal and cardiac tissues, further improving cardiovascular function and aerobic capacity[34,54,55] as recently reported in runners.[56]

Phytochemicals refer to active substances in plant foods that may provide unique benefits to highly active individuals. Thousands of dietary phytochemicals found in, for example, fruits, vegetables, nuts, and seeds (and their oils), legumes, and grains possess antioxidant and anti-inflammatory properties.[33,57] Whole-food plant-focused diets usually contain high amounts of phenolic acids, flavonoids, and carotenoids, which have strong antioxidant properties, and therefore remove the excess of active oxygen in the body and protect cells from damage.[58] The beneficial effects of these can lead to reduced exercise-induced oxidative stress and inflammation, and thus, enhanced endurance performance,[56] reduced muscle damage, improved immune function, and more efficient recovery from training and competition.[33]

The comparability of PB diets to those higher in ASF with regard to performance, along with the well-established health, environmental, and ethical benefits of PB diets, make it an appealing choice for many athletes.[37] Although athletes should not necessarily expect to experience health and performance improvements by eliminating animal-derived proteins, the inclusion of more plant proteins, fruits, and vegetables generally improves diet quality.

As always, the impact of dietary changes for an individual will vary widely depending on their current or "baseline" dietary pattern. Increasing intake and variety of plant foods while also choosing fish and poultry over red meat more often, such as seen in a plant-strong, whole-food, Mediterranean-style diet, appears to offer consistent health benefits.[59] A plant-focused eating pattern that still includes small amounts of higher quality ASF may be the most practical approach or "first step" for many athletes.

It is also important to note that an ethically based or sustainable dietary pattern does not always correlate with health. Vegan and mostly-PB diets generally have much lower environmental impacts than diets containing meat;[59,60] however, a vegan consuming excessive amounts of refined CHOs, added sugars, and ultra-processed foods is likely to be at greater risk for increased body fat levels and chronic diseases than an omnivore consuming meat along with an abundance and variety of whole PB foods.[61] For this reason, the healthiest approach to a PB diet is through focusing on whole-plant foods with the incorporation of minimally processed foods as needed, with limited intakes of ultra-processed foods (PB animal-food analogues, i.e., meats, poultry, cheese, and fast foods). However, inclusion of high-protein PB meat substitutes, protein powders, and plant milks can contribute to overall protein intake and may be helpful for some athletes requiring higher intake of protein-dense foods for muscular adaptations and/or during energy restriction.[62]

As with omnivorous diets, there are certain nutrients in PB diets that merit extra planning and attention to optimize health and performance for athletes. Nutrients to consider when following a strictly or mostly PB diet are canvassed below.

Macronutrients

Dietary Protein and Muscle Protein Synthesis

Resistance exercise training (RET) in combination with dietary protein supplementation or increased protein intake is common practice in athletes, recreational weightlifters, and active gym-goers to enhance muscle growth and strength. A single session of exercise stimulates muscle protein synthesis (MPS) rates and, to a lesser extent, rates of muscle protein breakdown (MPB).[63] RET potentiates the aminoacidemia-induced rise in MPS that, when repeated over time, results in gradual muscle protein accrual and hypertrophy. Although the feeding plus exercise combination is "more anabolic" than nutrition alone, RET exerts the greatest increase in post-training mixed-MPS (mostly myofibrillar but also includes mitochondrial and sarcoplasmic proteins) in the order of ~34% to over 100% from resting basal values (fasted) across 48 hours after a single exercise bout while in energy balance (EB).[63,64]

A comprehensive 2016 review[64] of dietary protein, RET, and MPS in dozens of studies determined that the average fasted-state post-RET increase in MPS for all studies and methods across multiple times suggests a post-exercise increase of 56% from resting values. The authors noted that although the magnitude and duration of MPS responses are dependent on exercise intensity/volume it appears that a fatiguing bout of RET, studied in the fasted state, results in elevated post-exercise MPS responses for up to 48 hours.[64] Importantly, their review also conveyed that total protein intake per day, rather than protein timing or quality, appears to be more influential during long-term exercise interventions[64], which will also be discussed in detail below.

The potent anabolic effects of RET have also been reported in young overweight males during energy restriction (ER).[65] This study aimed to determine the impacts of low (1.2 g/kg) and high (2.4 g/kg) protein intakes on MPS and MPB while performing unilateral (leg) resistance exercise during 10 days of 40%-reduced energy intake.[65] Their findings demonstrated that even in ER, RET can stimulate postabsorptive mixed MPS up to 48 h after an exercise bout, with no differences in low vs high protein intakes, in the resistance-trained leg.[65] These results are consistent with findings from an acute ER study[66] and another reported in EB[64], and further demonstrates that RET is providing the dominant anabolic signal to skeletal muscle.

Post-exercise protein ingestion is widely applied as a strategy to augment post-exercise anabolic stimulation to facilitate the 'muscle-specific' adaptive response to RET; however, the importance of protein ingestion or nutrient timing during this "anabolic window" has been overestimated.[46,64] Indeed, beyond a daily protein intake of 1.6 g/kg/day, protein supplementation does not meaningfully augment resistance exercise-induced muscle hypertrophy.[46] A 2018 meta-analysis reported that although the timing, dose, and source may influence the efficacy of protein supplementation on MPS, these variables do not necessarily translate into enhanced muscle protein accretion in a habitual resistance exercise setting.[46] Rather, a daily protein intake of ~1.6 g/kg/day (or as high as 2.2 g/kg/day) from animal or plant sources, separated into ~0.25-0.4g/kg doses/meals throughout the day, appears to be more influential on muscle protein remodeling when the goal is to optimize hypertrophy through resistance exercise-induced muscular adaptations.[67]

In summary, the above observations warrant emphasis when discussing the efficacy of plant proteins for stimulation of MPS when adopting an appropriate and robust RET-program. In contrast, protein source and timing, although important, are secondary factors to consider when optimizing adaptations to training.[64,65]

What About the Quality of Plant Proteins?

Historically, meat and other animal-derived foods and supplements (e.g., whey protein powders) have been viewed as critical components of an athlete's diet. Many animal-derived protein advocates question the adequacy of protein derived from a PB diet (Figure 1 & 2) to adequately support MPS for strength, hypertrophy, and recovery from high-intensity sport, training, or exercise.[68] Aside from adequate intake of total protein, the digestibility, absorption kinetics, and amino acid composition of a protein source are key factors in determining the ability of a protein to enhance post-exercise muscle remodeling.[69] Two requirements for a protein to be considered high-quality or complete for humans are having adequate levels of indispensable (essential) amino acids (EAAs) to support human growth and development, and being readily digested and absorbed.

Protein Digestion and Amino Acid Absorption

Following ingestion, dietary protein must be digested and absorbed for the amino acids to become available into circulation, where they can modulate MPS, MPB, and net protein balance (NPB). In general, PB whole foods have a lower absorbability when compared with animal-based whole foods primarily due to the presence of high levels of insoluble fiber, or high concentrations of antinutritional factors such as polyphenolic tannins and trypsin (protease) inhibitors.[70] For example, trypsin inhibitors found in legumes such as soy may inhibit the breakdown of soy protein. However, this is not a concern for all plant protein sources, and many of these potential

Food (serving size)	Calories (kcal)	Protein (g)	Leucine (g)
Tofu (extra firm) (3/4 cup / 185 g)	260	26	2.4
Edamame (cooked) (1 cup / 155 g)	190	19	1.2
Tempeh (cooked) (3 oz / 85 g)	165	17	1.2
Lentils (cooked) (¾ cup / 150 g)	170	14	1
Chickpeas (cooked) (¾ cup / 123 g)	200	11	0.8
Brown Rice with Black Beans (cooked) (½ cup ea. / 240 g)	230	10	1.0
Pumpkin Seeds (1 oz / 28 g)	160	9	0.7
Hemp Hearts (1 oz / 28 g)	155	9	0.6

Figure 1 Protein From Plants

impairments to absorption are resolved through soaking and sprouting, heating, fermentation, and other forms of processing.[71] Accordingly, most commercially available soybean products such as soy protein concentrate (70% protein), soy protein isolate (90% protein), soy-based infant formulas, soy milk, tofu, soy sauce, and miso typically receive sufficient heat treatment to cause inactivation of up to 80% of the trypsin inhibitor activity.[70] Since many plant-protein concentrates and isolates reach similar digestibility levels as conventional animal-based protein sources, this implies that the whole-food matrix can be problematic and not the plant-based proteins per se.[69] Furthermore, while so-called antinutrients can be deleterious, many are responsible for the unique health benefits of plant foods.[71]

The Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) currently recommend the Digestible Indispensable Amino Acid Score (DIAAS)[72] to quantify protein quality and better reflect what amino acids are being digested as opposed to calculating values based on fecal nitrogen excretion, which has several limitations.[73] In general, most animal-based protein sources, such as milk, whey, casein, eggs, and beef, have excellent protein quality scores, as they are complete proteins (i.e., contain all EAAs) and are highly digestible for supporting human growth and development requirements.[74] Like milk proteins, soy protein has an excellent quality score and is a good alternative to dairy milk as a quick and easy recovery beverage.

Several other plant-source proteins (e.g., canola, potato, pea, barley, lentils, and quinoa) are also considered to be of high quality when adequate amounts are ingested.[73] For example, a recent study[75] that aimed to assess the real ileal amino acid and nitrogen digestibility of pea protein isolate as compared to milk casein in humans reported that a DIAAS of 1.00 was obtained for pea protein as it demonstrated its ability to meet all amino acid requirements. This study shows the potential of pea isolate as a high-quality protein for use as a meat and dairy substitute,[75] in addition to being classified as an environmentally sustainable plant crop.[76]

For some athletes it may be difficult to take in relatively large amounts of protein from fibrous whole plant foods (grains, legumes, vegetables, nuts, seeds) because they typically have a lower percentage of protein, and large amounts may be required to meet protein intake goals of 25 g protein or more at one sitting. However, soy products such as extra-firm tofu, many PB meats, concentrated plant milks and an array of plant protein powder isolates and concentrates make it possible to consume 20 g or more of PB protein in one serving as ready-to-drink shakes, powder mixes, bars, and other PB food products.[77,78]

Although the DIAAS of a protein is based on the ileal digestibility of each individual EAA, this rating of quality does not account for the rate at which amino acids are being absorbed (absorption kinetics), where a more rapid rate of amino acid absorption is an independent factor that modulates the MPS response to feeding.[69] When using the postprandial rise in plasma amino acid concentrations as a proxy for protein digestion and amino acid absorption, data seem to suggest that plant-derived protein isolates or concentrates (used in PB protein powders, bars, alternative meats) are rapidly digestible and do not seem to differ substantially from most animal-derived protein sources.[79] In addition, as noted earlier, there does not appear to be a difference in the MPS response with subsequent strength and hypertrophic adaptations when protein intakes from a variety of sources (including exclusively plant-derived) reaches ~1.6 g/kg/day, separated into ~0.30+ g protein per kg per meal doses.[39,46]

Amino Acid Composition of Protein Source(s)

Following protein digestion and amino acid absorption, the post-meal MPS response is largely dependent on the rise in concentration of plasma EAA.[80] Consequently, proteins with higher EAA contents, importantly leucine, are more likely to robustly stimulate postprandial MPS. Animal-derived proteins as a whole generally contain higher EAA concentrations compared to plant proteins; however, many PB proteins such as soy, brown rice, canola, pea, corn and potato protein do meet the requirements for essential amino acid content recommended by the WHO/FAO/UNU (United Nations University).[81] In addition, the EAA contents of canola- (29%), pea- (30%), corn- (32%), and potato- (37%) derived proteins are comparable or in the case of potato protein (although palatability is low) may be, even higher than casein (34%) or egg (32%) protein.[82] For a comprehensive assessment of protein content and amino acid composition of several commercially available plant-sourced protein isolates, please see Gorissen et al. 2018.[82]

	Tofu** Stir-fry	Quinoa*** Chickpea Salad	Chicken Breast (115 g)	Eggs (3 large)
Total Protein (g)*	50	25	33	19
His	1.2	0.7	1.0	0.4
Ile	2.2	0.9	1.7	1.0
Leu	3.7	1.7	2.5	1.6
Lys	2.3	1.4	2.8	1.4
Met	0.7	0.4	0.9	0.6
Phe	2.3	1.2	1.3	1.0
Thr	2.0	0.8	1.4	0.9
Trp	0.6	0.3	0.4	0.2
Val	2.5	1.0	1.6	1.2

Figure 2 Protein and Amino Acid Comparisons of Animal and Plant Proteins

Similar to omnivorous meals, plant-based proteins are not consumed in isolation but as a mixed meal. Mixed plant meals are high in protein and essential amino acids.

*Values for nutrient tables sourced from Food Data Central https://fdc.nal.usda.gov/ Data are rounded to the nearest tenth.
**Protein sources: extra-firm tofu, broccoli, peanut sauce
***Protein sources: chickpeas, quinoa

Robust trial evidence has shown leucine to be the dominant amino acid driving anabolism and skeletal muscle accretion through MPS.[83] Whey protein has received much attention for muscle building due to its high level of leucine, whereas plant proteins tend to be lower in this BCAA and theoretically may not reach a similar anabolic threshold unless matched for leucine content.[45] The current leucine requirement within a given protein source is 5.9% by the WHO/FAO/UNU.[58] Whereas isolated or concentrated plant-based proteins like hemp (5.1% leucine) fall short, other proteins like oat (5.9%), spirulina (6.0%), and wheat (6.1%) protein provide close to the recommended leucine content.[81,82] Soy (6.9%), canola (6.9%), pea (7.2%), brown rice (7.4%), potato (8.3%), and corn (13.5%) protein have leucine levels that exceed the recommended requirements and are not much different from those levels found in casein (8.0%) and egg (7.0%) protein.[82]

Although assessments of protein quality and amino acid concentrations in single foods are valuable to our understanding of the potential shortfalls in consuming exclusively plant-sourced proteins, there are some practical implications and nutritional strategies to be cognizant of when assessing the strength of the muscle protein synthetic response. Firstly, individuals do not generally consume a single food item, especially when it comes to protein (e.g., a breast of chicken, block of tofu or cup of beans), but rather mixed meals that historically include a mix of plant and animal foods (e.g., chicken, rice, and vegetables). Mixed meals of solely plant-sourced foods shown in Figure 2 include values for total protein and the 9 essential amino acids. Three sample high plant-protein meals are compared to the protein content of what are considered "very high quality" animal-sourced proteins. In the given examples, protein and leucine content are equivalent to or surpass that contained in a serving of high-quality animal protein (served as a single food).

PB protein sources often lack one or more amino acids (but are often adequate in 19 of 20) in sufficient quantity to meet human nutritional needs.[21] But combinations of different proteins (Figure 2), including cereal-pulse combinations (e.g., rice and beans, chickpeas and quinoa), supplementation (plant protein powders such as soy, potato, rice, and pea-based), and fortified food products (e.g., plant milks and PB meats) can help to overcome this in strict vegan or plant-exclusive diets.[39] Figure 3 represents a series of potential barriers to achieving optimal protein intakes and their solutions to optimize plant protein quality and efficacy for the purpose of muscular adaptations.

Figure 3

(1) Plant proteins with high protein quality, but low protein content (e.g. potato), may include extraction of high-quality protein isolate forms to increase quality, an effective method to allow ingestion of a desired amount of protein.

(2) Plant proteins with deficiencies in specific amino acids (e.g. corn: low in lysine), can be fortified with the deficient free amino acid(s) to improve the amino acid content profile.

(3) Plant proteins with deficiencies in specific amino acids can be combined to improve the overall amino acid profile of the protein blend. For example, plants low in methionine but high in lysine can be combined with ones high in methionine but low in lysine. A combination of pea and brown rice protein is an example of a blend that would meet overall amino acid requirements.

(4) When plant-protein food sources (or protein isolates) are deficient in one or more amino acids (e.g. lentils, wheat), this may be compensated for by simply ingesting a greater amount of the plant-based protein source. Illustrations: the serving size represents the amount of food to be consumed to provide 20 g protein, unless otherwise indicated. Weight for brown rice and lentils represent cooked amounts.

Lastly, the terms “complete” and “incomplete” are misleading concerning plant protein, as this would only be relevant if one ate only rice or only beans for daily sustenance. Ingesting protein from various plant foods

Food (serving size)	Problems	Solutions (serving size)
Potatoes (cooked) (1050 g)	Low protein	**Protein extraction** (25 g)
Corn (cooked) (690 g)	Low protein Low in specific amino acids	**Protein fortification** (25 g)
Brown Rice with Peas (cooked) (240 g / 640 g)	Low in essential amino acids	**Protein blends (50/50 split)** (450 g)
Lentils (cooked) (230 g)	Low in essential amino acids	**Increase protein intake** ~300 (~25-30 g protein)

Figure 3 Plant Proteins: Problems and Solutions

over a 24 to 48 hour period will easily supply enough of all EAAs when total energy requirements are being met.[84] When significant gains in muscle mass or LBM preservation during energy (kcal) restricted diets are the goals, a greater focus on higher protein plant foods, plant protein isolates/concentrates, or other amino acid supplements is likely warranted.[62,65]

Plant Proteins and Muscular Adaptations: What Does the Research Show?

Due to higher energy intakes among individuals participating in sports and high-intensity exercise, the amounts and proportions of amino acids consumed by individuals following PB or vegan diets are typically more than sufficient to meet and exceed individual daily requirements, provided a good variety of plant proteins are consumed, and energy intake needs are being met.[44,85]

One study compared muscle strength using a 1 RM in leg and bench press in 28 vegans and 28 omnivores; participants were lean, physically active women who had been following their respective diets for at least 2 years.[35] Both groups were comparable for physical activity levels, BMI, % body fat, LBM, and muscle strength, suggesting that a vegan diet does not seem to be detrimental to muscle strength in healthy, young, lean women.[35]

Similarly, another study assessed strength through isokinetic leg extension in 27 vegetarian and 43 omnivore elite runners with similar protein (g/kg) intake; the study reported no difference in peak torque when performing leg extension, suggesting a vegetarian diet may adequately support strength.[41] More recently, a study combined ultrasound assessments of vascular and skeletal muscle properties, and maximal muscle force and VO2 max, and compared outcomes between untrained habitual vegan and omnivorous men. Their findings demonstrated no differences in vascular structure and function, or skeletal muscle properties, between individuals categorized as habitual vegan and omnivorous dieters despite lower protein and energy intakes in vegans.[86]

Many studies have reported no differences in plant vs animal-sourced protein powder supplementation.[43,45,47,79,87] However, overall dietary protein intake (i.e., meals, not supplements) may or may not be restricted to PB sources in the plant-protein supplemented group, therefore not eliminating the potential effects of animal-based proteins. To address this, in the most persuasive interventional trial to date, researchers compared the effects of a diet consisting of plant proteins exclusively vs an omnivorous diet on RT-induced muscle adaptations following a 12-week RT program in young males under an optimal protein intake (1.6 g/kg per day) combining whole foods plus supplemental protein (either soy or whey protein isolates). No significant differences were observed in increases in leg lean mass, muscle cross-sectional area CSA (rectus femoris and vastus lateralis), fiber CSA (type I and type II muscle fiber), and muscle strength following diet and resistance training between the two groups, regardless of dietary protein source.[39]

The beliefs and attitudes surrounding the superiority of animal-sourced proteins have dominated sports nutrition practices and guidelines for decades. However, a recent surge in plant protein research[39,43,47,75,78,82] and the rampant growth of PB foods and food products in the marketplace[88] have sparked interest and wider acceptance of this dietary pattern. Although a focus on minimally processed (i.e., tofu, tempeh, seitan, soy milks, mycoprotein) and whole food fungi or plant proteins (i.e., legumes, beans, nuts, seeds, whole grains, some mushrooms) is ideal to optimize intakes of unique phytonutrients and fungi-derived nutrients, the addition of some concentrated non-animal proteins may offer important advantages without compromising health or performance.[69,75,79,89,90]

Protein Recommendations

The Recommended Dietary Allowance (RDA) is 0.8 grams of protein per kilogram of body weight; however, the Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine[91] suggests that athletes should consume 1.2-2.0 grams of protein per kg to support the body's adaptations to exercise and increased protein turnover due to training. As with the RDA, no unique recommendation is given for athletes following vegetarian or vegan diets. As long as athletes consume adequate energy (kcal) from a well-balanced diet, vegetarian and vegan athletes should be able to consume the recommended amounts of protein through their diet.[92]

While there is general agreement about the need for more protein in hard-training athletes, the debate about whether certain types of proteins are more conducive for building muscle and strength than others appears to be waning as high-quality research into PB proteins and muscle and exercise physiology reveals that as long as higher protein intakes are being met (1.6 g/kg/day) protein source appears to be of little relevance.[39] Studies examining the dietary intake of vegan and vegetarian endurance athletes have also shown that these athletes are meeting their recommended daily needs for protein.[40,41] Food sources high in protein that are acceptable to sport-focused individuals following PB diets include soy products (tofu, tempeh, edamame, soymilk), pulses (beans, lentils, peas), and an array of plant-based meat substitutes and protein powders. Seeds, nuts, and whole grains, such as quinoa and plant-based milks, also contribute protein to the diet (see Table 1).

Food (serving size)	Protein (g)
Tofu (extra firm) (3/4 cup / 185 g)	26
Seitan (cubed) (⅓ cup, 40 g)	21
Tempeh (cooked) (1 cup / 100 g)	20
Edamame (cooked) (1 cup / 155 g)	19
Lentils (cooked) (1 cup / 200 g)	18
Black Beans (cooked) (1 cup / 240 g)	15
Soy Milk (original and vanilla) (1 cup / 250 mL)	6
Chia Seeds (1 oz / 28 g)	5

Table 1
Protein content of select food items

Is it Okay to Eat Soy?

Whether published on social media, in a popular press article, or a well-designed clinical study, some debate about soy remains. Part of the uncertainty is due to the misunderstanding of the bioactive components of soy and their effects on the body.[77,93] Soy is unique in that it contains a high concentration of isoflavones (high in soybeans, but lower content in most soy food products), a type of plant estrogen or phytoestrogen, that is similar in function to human estrogen but with much weaker effects.[77] Soy protein is considered a complete protein, containing all nine EAAs that the body cannot make, which must be obtained from the diet.[69] Unfermented soy (e.g., tofu, edamame, soy milk) is a valuable source of high-quality protein, with extra-firm tofu being one of the densest sources of plant protein available (Figure 1). Fermented soy (e.g., tempeh, natto, miso) has been cultured with beneficial bacteria, yeast, or mold, improving its digestibility and absorption in the body.[94]

SOY PROTEIN IS CONSIDERED A COMPLETE PROTEIN, CONTAINING ALL NINE ESSENTIAL AMINO ACIDS THAT THE BODY CANNOT MAKE.

Although foods made from soybeans such as tofu have been a staple in Asian diets (as well as Asian elite athletes' diets) for centuries, they have recently become more popular in the West due to increased interests in the health of PB diets and the search for high-quality plant proteins.[93] Studies have consistently shown that soy protein significantly reduces LDL cholesterol by approximately 3-4% in adults.[95,96] This has resulted in the Food and Drug Administration (FDA) of the United States (US) recognizing that the consumption of soy protein decreases the risk of cardiovascular diseases and allowing soy-based foods to apply the coveted "healthy" food label, which has increased public interest in soybeans.[95]

Phytoestrogens (e.g., soy isoflavones) are common to nearly all plant foods, structurally similar to estradiol, and known to improve vascular function and blood flow.[97] Indeed, isoflavones are thought to augment vascular endothelial relaxation and contribute to improved limb blood flow, which investigators recently tested in a group

of trained male cyclists.[55] In the randomized controlled trial, cyclists who received isoflavones in a fermented soy extract supplement elicited a faster time to the 20 km completion, a lower average heart rate, and significantly greater power and speed during the last 5 km of the time trial compared with the placebo group.[55]

Although males also produce estrogens (at much lower amounts than females), male athletes have been concerned about consuming phytoestrogens due to their potential feminizing or testosterone-lowering properties. Low testosterone can be linked to diminished sex drive, reduced muscle mass, depression, fatigue, and weaker bones but the evidence for this has not persisted as more research on this topic has been published.[98] The isoflavones in soy products were thought to act as endocrine or hormone disruptors, as seen in animal studies in the 1990s.[77] Over the past several decades the health effects of soy foods and soybean isoflavones have been rigorously researched. In 2010 (and updated in 2021) a paper including 47 studies that examined the relationship between soy foods and products and male sex hormones, including testosterone, concluded that soy intake did not significantly affect testosterone levels.[98] Well-designed human trials show that adverse effects are also not seen on women's breast tissue or estrogen levels, or on the testosterone or estrogen levels in men's sperm or semen parameters.[77,98] A recent meta-analysis provided the strongest evidence to date, showing a lack of support for classifying isoflavones as endocrine disruptors.[77]

Practically, isoflavones are very low in soy protein isolate or concentrate (used in plant-based protein powders, veggie burgers, energy bars, and other food products) due to processing methods that remove as much as 90% of the isoflavone content, compared to tofu or soymilk.[77] These forms of soy are often the main protein sources for athletes who primarily use soy protein powders, soy-based protein/energy bars, with occasional intakes of PB meat alternatives as burgers, hot dogs, and sausages among others. The use of soy-based protein powders in the sport and fitness communities is common since they can offer a comparable amount of leucine and protein to whey powders when ingested at a higher dose upwards of 40 grams or when leucine is added to the product (by the individual or the manufacturer) in the form of fermented leucine or BCAA.[82]

Several resistance- and endurance-training studies have compared whey, which is high in "anabolic leucine", to soy protein and investigated their effects on hypertrophy and strength outcomes. A recent meta-analysis of 9 clinical trials concluded that soy protein led to similar gains in muscle mass and strength as whey protein and other types of animal protein.[43] Similarly, in a 12-week trial, vegan males using a soy protein isolate supplement made similar gains in muscle strength and mass accrual to omnivore males using a whey protein isolate, suggesting that protein source does not affect resistance training-induced adaptations in young men consuming adequate amounts of protein.[39] As previously mentioned, cyclists who received a fermented soy extract supplement elicited a faster time to the 20 km completion among other benefits.[55] Another investigation published in older adults also supported the efficacy of soy for maintaining and building lean mass and strength.[87]

In summary, soy is a high-quality, complete PB protein that has been shown to support hypertrophy and strength gains, and improved aerobic capacity, while also offering additional cardiometabolic advantages. Soy foods and supplements are recommended as part of a healthy well-balanced PB diet to support exercise and sport performance.

Omega-3 Fats

Omega-3 (n-3) polyunsaturated fatty acids (PUFA) are essential fatty acids with diverse biological effects (especially in the brain, retina, and sperm) that must be consumed through dietary or supplement sources due to a lack of ability for de novo synthesis of PUFA in humans.[99]

Some studies have shown that n-3 fats may positively influence muscle mass and function in older adults[100] and some evidence for preservation of strength and enhanced recovery from heavy exercise in younger adults,[101,102] potentially through their anti-inflammatory effects.[103] However, a recent systematic review of 18 studies[104] reported null or weak effects for muscle preservation and low-to-moderate evidence for strength and recovery. Similarly, another report in older adults at risk of sarcopenia did not observe a beneficial effect of n-3 supplementation on appendicular lean mass, strength, physical performance, or myofibrillar protein synthesis.[105] Although study findings have been mixed, athletes should still ensure adequate intake of these essential fats.

The n-3 fatty acid biosynthesis pathway converts alpha-linolenic acid (ALA) to eicosapentaenoic (EPA) acid and further into docosahexaenoic acid (DHA, integral to the visual process and synaptic functioning). ALA is found mainly in nuts, seeds, and plant oils, and DHA and EPA are found in fish and other seafood but they are originally synthesized by microalgae, not by the fish.[106] While intakes of plant n-3s or ALA are

Table 2 Alpha-linoleic acid (ALA) content of select food items

Food (serving size)	**Flaxseed Oil** (1 tbsp / 14 g)	**Chia Seeds** (1 oz / 28 g)	**English Walnuts** (1 oz / 28 g)	**Flaxseed (whole)** 1 tbsp (15 g)	**Canola Oil** (1 tbsp / 14 g)	**Soybean Oil** (1 tbsp / 14 g)	**Black Walnuts** (1 oz / 28 g)
ALA (g)	7.3	5.1	2.6	2.35	1.3	0.9	0.76

generally higher in those following PB diets compared to omnivores, intakes of EPA and DHA are low in PB diets and virtually absent in vegans or plant-exclusive diets.[106] Despite the assumptions that PB eaters/vegans are at risk of deficiency due to low conversion of ALA to EPA and then to DHA,[107] there does not appear to be strong evidence of deficiencies in adults.[108] Although fish-eaters in general have higher circulating levels of DHA, some reports have shown female vegans to potentially have higher (or at least not different) circulating DHA levels, with zero consumption, compared to fish-eaters,[109] which is likely due to higher-than-average intakes of ALA.

Recent evidence has brought into question aspects of the n-3 synthesis pathway that researchers thought were well understood, including the low rates of DHA synthesis (due to low conversion ALA to EPA to DHA),[110-112] which highlights the likelihood that PB eaters can maintain their serum DHA levels through consumption of ALAs only. Currently there is no recommended daily allowance (RDA) for EPA or DHA; therefore, those following a vegan or PB diet should focus on consuming adequate amounts of ALA (see Table 2 for ALA-rich foods) which may be higher than the current adequate intake (AI) recommendation which is 1.2 g and 1.6 g per day for adult females and males, respectively.[113] Although consuming pre-formed DHA (fish, supplements) is likely unnecessary, vegans or those following a PB diet also have the option of obtaining DHA directly through vegan-friendly algal supplements.[113]

Micronutrients

Vitamin B12

Vitamin B12 (cobalamin) is not synthesized by humans and the only dietary sources are foods of animal origin and fortified foods (e.g., nutritional yeast flakes, breakfast cereals, energy bars, plant milks, and others). Vitamin B12 is important for normal brain and nervous system functioning and helps to make DNA.[114] Symptoms of B12 deficiency include brain fog, memory problems, fatigue, lethargy, irritability, and moodiness. Vitamin B12 is also associated with red blood cell (RBC) formation and low levels may result in megaloblastic anemia.[115] Megaloblastic anemia limits the blood's oxygen carrying capacity, thus reducing its availability to cells, which may negatively impact aerobic performance.[115] Individuals following PB diets must take particular care to consume enough vitamin B12, as it is mainly found in meat, eggs, and dairy products. Although vitamin B12 deficiency is relatively uncommon in omnivores, there is an increased risk in populations of lower economic status and among older people >60 years whether omnivore or PB eaters.[116]

Despite some reports in popular media, studies on naturally occurring and vitamin B12-containing plant-derived food sources show that only nori (seaweed) is suitable as a vitamin B12 source for vegetarians.[117,118] However, due to inconsistencies and variability in plant sources of B12 content, the only reliable PB/vegan dietary sources of B12 are fortified breakfast cereals and nutritional yeasts, along with PB meat substitutes, PB milks, and other PB fortified food products.[119] Those following a PB or vegan diet should take a B12 supplement (cyanocobalamin is recommended) at least once per week and track intakes derived from B12-fortified foods and beverages.[92,119]

Iron

Iron is an essential mineral that plays a significant role in exercising individuals since it is required for oxygen transport, energy, metabolism, and building a strong immune system. Iron also enables erythropoiesis, the production of red blood cells (RBCs).[120] RBCs supply oxygen to all organs and tissues in the body including skeletal muscle and the heart. Despite its importance, athlete populations, both omnivore and vegetarian, and especially females and endurance athletes, are commonly diagnosed with iron deficiency.[121] All types of iron deficiency may affect physical performance and should be treated accordingly through dietary modifications (including fortified foods) or the use of supplements.[122] Low iron status is determined by measuring certain blood markers such as ferritin, hepcidin, or transferrin. (Figure 4).

Iron-deficiency anemia is the most common type of anemia among athletes. Athletes have higher iron requirements due to increased erythropoietic drive through higher intensities and volumes of training, as well as losses through sweat, foot strike hemolysis, and GI bleeding.[123,124] There are two major forms of iron found in food: heme iron, which is only found in animal products, and non-heme iron, which is found in both plant foods and animal products. Although the bioavailability of heme-iron is superior to non-heme iron, mineral absorption also depends on the iron status of the athlete (absorption is higher when iron stores are low) and dietary inhibitors, such as calcium, phytic acid, polyphenols and peptides (from partially digested proteins), and enhancers such as vitamin C and muscle tissue.[125]

Owing to diets rich in whole grains, legumes (good iron sources), and the abundance of fortified PB meats and milks, both PB eaters and vegans consume similar amounts of iron as omnivores;[49,126] however, the risk of iron deficiency may[127] or may not[128] be greater due to lower bioavailability of iron from plant foods. Accordingly, recommended iron intakes for individuals following PB or vegan diets are 1.8 times higher than for omnivores who consume ASF: 32 mg/day (vs. 18 mg/day) for premenopausal adult women and 14 mg/day (vs. 8 mg/day) for adult men and postmenopausal women.[129] Table 3 displays iron content of selected plant-based foods.

Food (serving size)	Iron (mg)
Lentils (cooked) (1 cup / 200 g)	6.0
Chickpeas (cooked) (1 cup / 165 g)	5.2
Tofu (½ block / 170 g)	3.7
Black Beans (cooked) (1 cup / 240 g)	3.6
Quinoa (cooked) (1 cup / 185 g)	2.8
Pumpkin Seeds (1 oz / 28 g)	2.3
Cashews (1 oz / 28 g)	1.7
Dried Apricots (¼ cup / 33 g)	0.9
Spinach (raw) (1 cup / 30 g)	0.8
Hemp Seeds (1 tbsp / 10 g)	0.8
Dried Figs (¼ cup / 37 g)	0.8
Chia Seeds (1 tbsp / 12 g)	0.6
Kale (raw) (1 cup / 21 g)	0.4

Table 3
Iron content of select food items

	Serum Ferritin (µg/L)	Hemoglobin (g/L)	Transferrin Saturation (%)
Stage 1–Low iron	<35	>115	>16
Stage 2–IDNA	<20	>115	<16
Stage 3–IDA	<12	<115	<16

Figure 4 Stages of Iron Deficiency

Routine screening for iron status should be considered in both male and female athlete populations, regardless of dietary pattern.

Stage 1–Low iron storage

Ferritin is the storage form of iron, and low ferritin levels are the first sign that the body's iron stores are compromised. Impacts to performance are likely low.

Stage 2–Iron deficiency non-anemia (IDNA)

During the second stage of iron deficiency, red blood cell (RBC) formation and transport iron (transferrin) both decrease. Hemoglobin levels remain normal. Impacts to performance are likely.

Stage 3–Iron deficiency anemia (IDA)

Hemoglobin production drops and results in anemia. At this stage RBC are fewer in number, smaller, and contain less hemoglobin. Impacts to performance are very likely and may be severe.

Zinc

Zinc is a trace mineral abundantly distributed throughout all body tissues and fluids, and second only to iron among trace elements in the body. It is essential for multiple aspects of metabolism, including catalytic, structural, and regulatory functions, and also plays an important role in gene expression and the immune system.[130] Deficiency of this mineral can lead to hair loss, poor healing of wounds, immunological problems, skin problems, and reproductive hormone imbalances.[131]

Plant sources of zinc have lower bioavailability due to the presence of phytates (which are in legumes and whole grains) that bind zinc and inhibit its absorption.[132] Because of this reduced bioavailability, those following a vegetarian or strict PB diet may require up to 50% more zinc compared to omnivores.[122] This equates to male vegetarians needing 16.5 mg of zinc and female vegetarians needing 12 mg of zinc daily. Some preparation techniques that increase the bioavailability of plant sources of zinc include soaking and sprouting beans, nuts, seeds, and grains; leavening (bread has more bioavailable zinc compared to crackers); and using organic acids with zinc such as citric, malic, or lactic acid.[92,133] Some researchers suggest supplementation may be advisable for vegan athletes,[134] but this is not universally agreed upon. Soy, legumes, grains, seeds, nuts, beans, and fortified cereals are acceptable zinc sources for vegans and vegetarians. Table 4 provides a list of some zinc sources.

Food (serving size)	Chickpeas (cooked) (1 cup / 165 g)	Pumpkin Seeds (1 oz / 28 g)	Tempeh (cooked) (1 cup / 100 g)	Lentils (cooked) (1 cup / 200 g)	Tofu (extra firm) (0.2 block / 85 g)	Almonds (1 oz / 28 g)	Whole-wheat Bread (1 slice / 39 g)
Zinc (mg)	2.5	2.2	1.9	1.3	1.0	0.9	0.6

Table 4
Zinc content of select food items

Iodine

Iodine is a trace element and an essential micronutrient for the body. Iodine is vital for the synthesis of thyroid hormones, which regulate many important functions in the body including neurological development, protein synthesis, enzymatic activity, and other aspects of metabolism.[135] Iodine content of plant foods is inconsistent, as it is largely dependent on the iodine content of the soil.[136] Populations in regions where the iodine concentration in the soil is low are at risk of iodine deficiency unless they receive dietary or other sources of additional iodine.[136]

Iodized salt fortification programs, which many countries have implemented, have dramatically reduced the prevalence of iodine deficiency worldwide.[135] Although concentrations may vary by country, iodized salt in the United States contains 45 mcg iodine/g salt (between 1/8 and 1/4 teaspoon).[137] The recommended intake of iodine for adults is 150 mcg/day. Adults following vegan and vegetarian diets living in countries with a high prevalence of deficiency may be more vulnerable. In a recent meta-analysis, vegans were reported to have the lowest median UICs, followed by vegetarians.[138] Vegans appear to have increased risk of low iodine status, deficiency, and inadequate intake compared with adults following less restrictive diets.[138]

For individuals, iodine status is typically assessed using urinary iodine concentrations (UICs) through the collection of multiple 24-hour urinary iodine, or multiple spot urine measurements are most accurate for individuals.[139] Plant-based or vegan athletes should make sure sources of iodine either from iodized salt, a multivitamin, or supplement containing potassium iodide are included in their diet. Sea vegetables (such as seaweeds like wakame, kombu, or nori) are a rich source of iodine, but caution is warranted as high intake of iodine can be harmful and the content in marine sources is highly variable. Table 5 displays iodine content of select plant-based foods.

Food (serving size)	Iodine (mcg)
Seaweed (nori, dried) (4 sheets / 10 g)	232
Whole-wheat Bread (with iodate dough conditioner) (1 slice / 39 g)	198
Iodized table salt (¼ tsp / 1.5 g)	76
Enriched Pasta (boiled in water with iodized salt) (1 cup / 110 g)	36
Soy Beverage (1 cup / 250 mL)	7
Almond Beverage (1 cup / 250 mL)	2
Apple Juice (1 cup / 250 mL)	1
Brown Rice (cooked) (½ cup / 100 g)	1
Non-iodized Sea Salt (¼ tsp / 1.5 g)	<1

Table 5
Iodine Content of select food items

Calcium, Vitamin D, K2, and Bone Health

Calcium is an essential nutrient required for building and maintaining bone strength. It helps maintain the integrity of the skeleton as part of hydroxyapatite. Additionally, calcium is involved with muscle contraction, vasoconstriction and dilation, normal blood clotting, hormonal responses, and nerve conduction.[140] Inadequate dietary calcium and vitamin D increase the risk of low bone mineral density and stress fractures, which are a common injury in many sport disciplines.[141] The RDA for calcium for males and females ages 19-50 is 1,000 mg per day.[140] Vegetarians who include dairy in their diets tend to consume similar amounts or more calcium compared to omnivores, although people who follow vegan diets tend to consume less calcium.[49,126,142]

Consuming a supplement of both vitamin D and calcium has been shown to be protective against bone fractures in vegans.[143] Plant sources of calcium may be less bioavailable due to the presence of oxalic acid[140] and to a lesser extent phytates and fiber.[92] The International Olympic Committee consensus statement on dietary supplements and the high-performance athlete posits that calcium and vitamin D are nutrients that often need to be supplemented for athletes, regardless of their dietary pattern.[144] Table 6 presents calcium content and variability in absorption rate of select plant-sourced calcium foods.

Vitamin D, along with calcium, is an important nutrient for optimizing bone health. Sufficient vitamin D is needed to absorb calcium and phosphate, contribute to normal functioning of most cell types in the body, and it also plays an important role in immunity.[145] Vitamin D deficiency is associated with muscle weakness, fatigue, depression, and bone pain.[145] Currently the RDA for males and females ages 19-50 is 600 International Units (IU) per day.[140] The International Olympic Committee consensus statement on dietary supplements and the high-performance athlete suggests that vitamin D supplements are commonly required for athletes, not just for vegetarians.[144]

Vitamin D can be synthesized by the skin from UV light[146] or can be obtained through the diet, although it is not found naturally in many foods. Factors affecting how much vitamin D is synthesized by the skin's exposure to sunlight include skin pigmentation, as well as the amount and intensity of sun exposure; which is affected by the time of day, season, and latitude.[147] Research has shown no significant differences between vegetarians and omnivores with respect to serum 25-hydroxyvitamin D status.[148] Food sources providing vitamin D include UV-irradiated mushrooms and fortified foods such as plant-based milks, orange juice, and cereals. It has been suggested that it may be beneficial for athletes to supplement 1,000-2,000 IUs/day, particularly if the athletes have minimal sun exposure.[146]

Vitamin K is a family of essential, fat-soluble vitamins required for blood coagulation, but also involved in deposition and removal of calcium in various tissues. The family comprises two naturally active vitamers: vitamin K1 (phylloquinone) occurs in green vegetables and plant oils, and vitamin K2 (menaquinone). Menaquinones are principally of bacterial origin, but a small amount of MK-4 can be formed in mammals (including humans) through conversion of phylloquinone in plant feed or provided to animals as a feed additive.[149] Research shows that vitamin MK-4 derived from plant-sourced vitamin K1 is likely satisfactory to meet vitamin K needs and animal-derived MK-4 sources are not necessary.[150]

In summary, although data suggest that a well-planned, health-conscious lacto-ovo-vegetarian and vegan diet, including supplements, can meet athlete's requirements for micronutrients, it may still be prudent to periodically check blood values of primarily vitamin B12, vitamin D, and iron[151] as discussed below.

Food (serving size)	Turnip Greens (raw, chopped) (1 cup)	Chinese Cabbage (raw, shredded) (1 cup)	Kale (raw) (1 cup)	Soy Milk (original and vanilla) (1 cup)	Tofu (extra firm) (0.2 block)	White Beans (cooked) (1 cup)	Unsalted Almonds (1 oz)	Tahini (1 tbsp)	Oranges (1 fruit)	Dried Figs (1/4 cup)	Beet Greens (raw) (1 cup)	Spinach (raw) (1 cup)	Swiss Chard (raw) (1 cup)
Calcium (mg)	104	74	53	299	257	161	74	64	61	60	45	30	18
	Low oxalate content High absorption rate (~50%)			Moderate absorption rate (~30%)		Lower absorption rate (~20%)					High oxalate content Lowest absorption rate (~5%)		

*Values for nutrient tables sourced from Food Data Central https://fdc.nal.usda.gov/ Data are rounded to the nearest tenth. Oxalate content and absorption rates in Table 6 based upon Melina et al. 2016.[92]

Table 6
Calcium content, absorption rate, and oxalate content of select food items

Taurine

Taurine is a sulfur-containing conditionally essential amino acid found in meat, fish, and dairy, that plays many diverse physiological roles involving glucose and lipid regulation, energy metabolism, as well as anti-inflammatory and antioxidant actions.[152] Individuals following a strictly PB diet lack pre-formed dietary taurine due to its non-existence in plant foods, however, the in vivo synthesis of taurine using dietary methionine and cysteine precursors largely accommodates for the lack of dietary intake.[153] As such, taurine does not appear to be an essential nutrient for healthy non-pregnant individuals following a PB/vegan diet.[153] Methionine and cysteine are the principal sulfur-containing amino acids because they are two of the 20 canonical amino acids that are incorporated into proteins for functional and structural purposes in our body.[153] Methionine is an EAA that through a sequence of reactions can be converted to cysteine which is a precursor of taurine and the antioxidant glutathione.[154]

Previous research has reported that plasma taurine concentrations are insignificantly and only slightly lower in vegans, compared to meat-eating omnivores, despite a large disparity in dietary intake.[155] Those following a PB diet should ensure adequate intake of the taurine precursors methionine and cysteine, found in plant proteins such as nuts and seeds, and beans and lentils, respectively. Synthetic (vegan-friendly) taurine is also often added to soda and energy drinks and is available as a supplement.

Similar to creatine and carnosine discussed below, individuals who do not consume animal muscle have much lower intakes of taurine. Plasma levels are also generally higher in those who consume taurine naturally from meat, dairy, and fish, but most people will not consume enough to meet the doses used in health or sport performance studies.[156]

Taurine used in doses of ~1–3 g/day acutely (1–3 h before an activity) has become a popular supplement among athletes attempting to improve performance, but the studies have been mixed.[156] For a review that summarizes the current evidence regarding the efficacy of taurine in aerobic and anaerobic performance, metabolic stress, muscle soreness, and recovery please see Kurtz et al. 2021.[156]

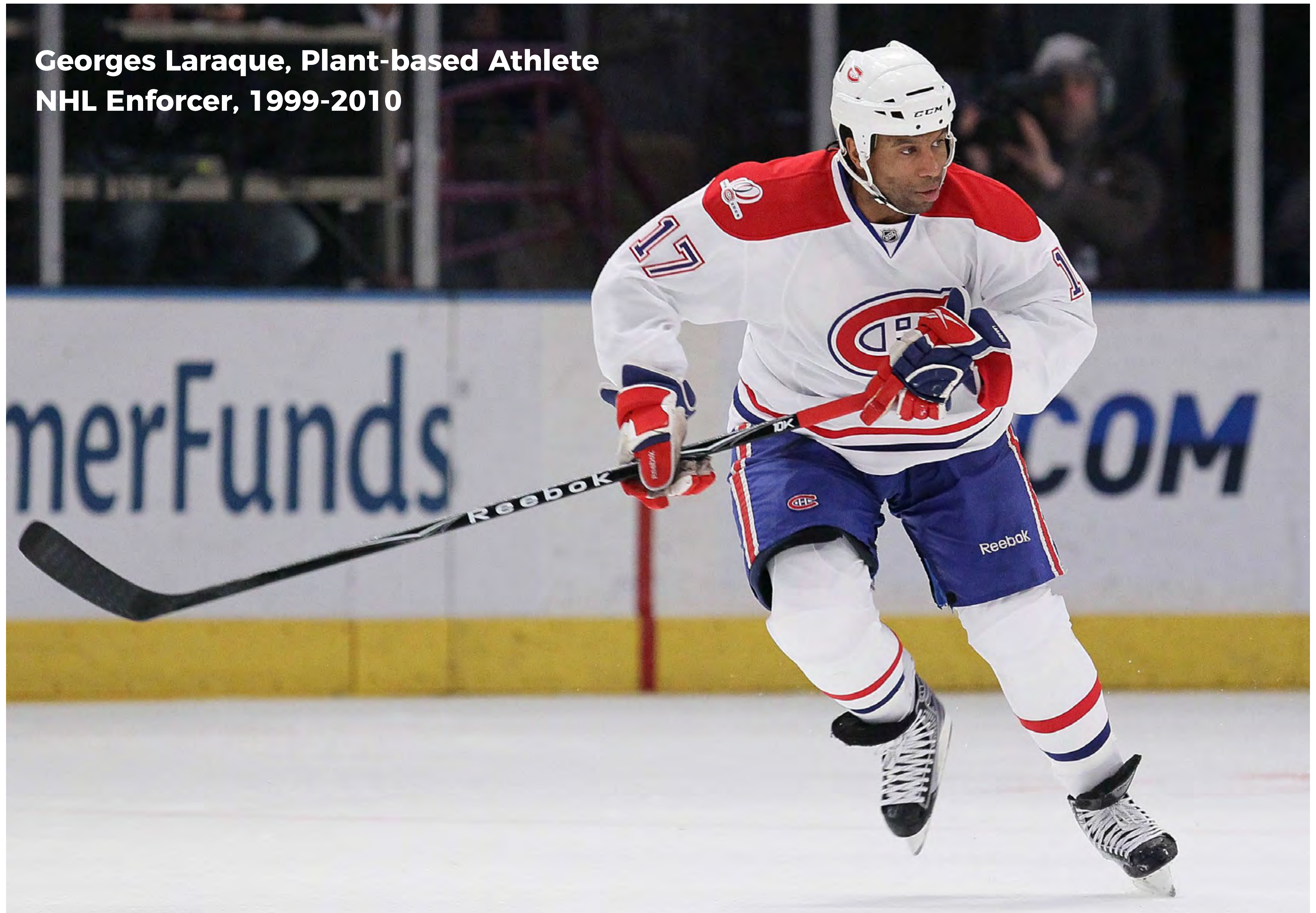
Should Vegans Test for Nutritional Deficiencies?

There are numerous health advantages to a plant-based/vegan diet but there can still be some vulnerabilities when it comes to ingesting adequate levels of certain nutrients that may be more concentrated in animal-sourced foods, or where consuming fortified foods (e.g., plant milks for vitamin D and calcium) or supplements may be necessary. Blood tests are a good way of confirming optimal internal organ function and screening for potential vitamin and mineral deficiencies. Some of these nutrients are commonly insufficient in omnivore diets as well, such as vitamin D and iron, especially in females.

A Blood Profile for Vegans May Include:

- **CBC** – provides detailed information about your red and white blood cells and can be used to detect conditions such as anemia caused by iron and/or vitamin B12 deficiency.
- **Vitamin B12** – a measurement of vitamin B12 in your blood.
- **Iron and Ferritin** – a measurement of iron and ferritin levels (a marker of the body's iron stores).
- **Iodine** – a measurement of thyroid function and/or urinary iodine concentration (UIC).
- **Zinc** – deficiency can be diagnosed using a blood test, urine test, or hair analysis.
- **D-25 Hydroxy (Vitamin D3)** – is the form of vitamin D commonly measured to assess and monitor vitamin D status.
- **Lipid Profile** – this test measures triglycerides and levels of cholesterol and the sub-fractions including HDL cholesterol and LDL cholesterol.
- **HbA1C** - measuring glycated hemoglobin (HbA1c) can provide an overall picture of what average blood sugar levels have been over a period of weeks/months.

If your test results show that you are experiencing a deficiency in one or more nutrients, you can take action and modify your dietary decisions by choosing more nutrient-specific and nutrient-dense foods, including fortified foods. Changing your dietary intake goals may also require you to use supplements. Common supplements taken by vegans include algal omega-3s, iron, vitamin B12 and D3, and possibly iodine. A daily or multiple times per week multi-vitamin/mineral may also be warranted. Athletes should discuss the use of supplements with their health care provider or nutrition professional.



Georges Laraque, Plant-based Athlete
NHL Enforcer, 1999-2010

Ergogenic Aids

Creatine

Supplements claiming to directly or indirectly enhance performance are typically the largest group of products marketed to athletes, but only a few have strong evidence showing benefits. Creatine is one such supplement, and one of a handful of ergogenic aids supported by high-level sport organizations such as the International Olympic Committee (IOC).[157] Increased muscle creatine content can help athletes generate and recover from quick, explosive movements at high intensities, enhance performance in strength and power events, and support increases in strength and hypertrophy by enabling more total work or volume in a single training session.[158] Over 90% of the body's creatine is stored in muscle as phosphocreatine (PCr) and free creatine.[159] Total creatine concentration in skeletal muscle tissue is higher in omnivores compared to vegetarians since the body synthesizes approximately 1g per day of creatine endogenously, and food in the form of meat, fish, and poultry provides an additional 1g.[160]

Dietary intake of creatine is low or absent in individuals following a PB or vegan diet,[160] which is reflected in their lower skeletal muscle total creatine stores.[161] Although it is assumed that those following a strictly PB diet would experience greater ergogenic benefits from creatine, due to lower muscle PCr stores, to date no strong evidence for this has been reported. A 2003 study often cited to support these claims reported a benefit from creatine supplementation in both vegetarians and omnivores in a variety of performance and muscle physiology outcomes, with vegetarians benefitting even more in two areas: lean tissue gains (not skeletal muscle specifically) and work volume.[162] However, in this study the protein intake in the vegetarian group was inadequate for the purpose of strength gains and hypertrophy (~0.8 g/kg), at just over half the amount consumed by omnivores (1.4 g/kg).[162] In addition, omnivores also ingested ~20% more energy (kcal). The vegetarian and omnivore groups were neither isocaloric nor isonitrogenous, and both of these factors may have confounded the findings.[162]

It appears that supplementation is likely equally beneficial for both omnivores and vegetarians/vegans, whereas baseline diet (i.e., diets including creatine from animal muscle) may be less impactful in driving such performance or muscle protein accrual advantages. Indeed, a recent review reported that taken together, creatine supplementation has the ability to increase performance in vegetarians as well as omnivores.[160] However, the research is not conclusive on whether vegetarians show a greater increase in performance than their omnivore peers.

The amount of creatine that is used in supplemental form to improve performance is 5g per day as a maintenance dose, and 20 g per day for ~7 days as a loading dose, which cannot be practically achieved through dietary intakes alone. For example, an individual would have to consume 35 oz of beef, salmon, or pork per day to reach the recommended daily maintenance dose of 5 g creatine per day as prescribed to achieve an ergogenic benefit.[160]

Emerging evidence also suggests that creatine supplementation may help to improve cognitive processing, especially in conditions characterized by brain creatine deficits, which could be induced by acute stressors (e.g., exercise, sleep deprivation, anxiety) or chronic, pathologic conditions (e.g., mild traumatic brain injury, aging, depression).[163,164] Since creatine is deemed to be safe and appears to have both ergogenic and health benefits, PB or vegan athletes and active individuals may wish to ingest an ongoing maintenance dose of 1-3 g creatine per day, to match the intakes of their omnivorous counterparts. For the purpose of performance enhancement, PB or vegan athletes can both follow guidelines for creatine supplementation as outlined by various sport organizations such as the IOC consensus statement on dietary supplements.[157]

Carnosine & Beta-Alanine

High-intensity exercise leads to a reduction in muscle pH (or increased acidity) due to hydrogen ion accumulation. Acidosis negatively impacts performance via a range of mechanisms, including reducing the capacity for muscle contraction and slowing the rate of ATP regeneration. Carnosine is a dipeptide formed by two amino acids, beta-alanine and L-histidine, and plays an important role in muscular pH-buffering in skeletal muscle during exercise, along with other physiological roles such as metal-ion chelator and antioxidant.[165] Carnosine is found in skeletal muscle (humans and other mammals) and the central nervous system, and is synthesized in situ from its rate-limiting precursor beta-alanine.[166]

Beta-alanine supplementation increases skeletal muscle carnosine content, and with it, the buffering capacity of the muscle (i.e., its capacity to regulate pH). This buffering ability has been shown to improve exercise performance, with its greatest effect in sustained, high-intensity efforts lasting between 30 seconds and 10 minutes.[167] Muscle carnosine also tends to be lower in vegetarians compared to omnivores.[168]

Although meat and poultry are the main sources of beta-alanine in the diet, there does not appear to be a significant relationship between dietary beta-alanine consumption and muscle carnosine content.[168] Therefore, athletes following any dietary pattern would benefit from beta-alanine supplementation to increase muscle carnosine concentrations.[167] The amount of beta-alanine that is used in supplemental form to improve

performance is 1.6 to 6.4 g per day for several days prior to an event, which is equivalent to approximately 24 oz of poultry per day to reach the equivalent beta-alanine dose required to enhance performance.[168]

Therefore, if applicable to the athlete both creatine and beta-alanine supplementation is recommended, rather than reliance on large portions of animal muscle tissue for several days or weeks to elicit a potential ergogenic advantage. This recommendation would apply to both PB/vegan and omnivorous athletes as the amount of animal muscle protein that is required to achieve performance-supporting or enhancing levels of either substance is far greater than what is recommended for human and planetary health.[169]

Summary

A well-designed, whole foods PB diet that includes some fortified foods and optional supplements can provide adequate macro- and micro-nutrient intakes for athletes and active individuals in support of health and performance. Abundant choices in the marketplace also offer convenience and novelty with a wide selection of fortified food products and supplements for those choosing to follow a PB diet. Athletes in general should be taking extra care to plan out their sport nutrition strategies whether they choose to follow a strict omnivore diet or a PB diet.

Although we have a vast amount of evidence in support of the nutritional adequacy and health benefits of PB diets, the sporting world's perception of PB diets may still create challenges to widespread implementation. Sports nutrition guidelines are regularly reviewed to incorporate new scientific evidence, and it is now time to welcome the viability of PB options to athletes. With the increasing evidence that plant-based diets support optimal health, performance, recovery, and body composition goals, the dissemination of accurate information to athletes and coaches is an important step in supporting the widespread transition to diets richer in traditional plants; such as fruits, vegetables, and whole grains, as well as plant proteins such as nuts, seeds, legumes, and novel minimally processed meat and dairy alternatives.

OVERVIEW OF THE MAJOR FOOD CATEGORIES IN A PLANT-BASED DIET

Vegetables including:
Peppers
Broccoli
Corn
Asparagus
Lettuce
Spinach
Kale
Peas
Collards
Tomatoes
Cauliflower
Brussel sprouts
Cucumber
Eggplant

Fresh fruits including:
Berries
Apples
Bananas
Grapes
Citrus fruits
Cherries
Peaches
Mango
Avocados

Dried fruits including:
Figs
Dates
Raisins
Apricots

Tubers and root vegetables including:
Potatoes
Carrots
Parsnips
Sweet potatoes
Beets

Legumes:
Beans of any kind
Lentils
Pulses
Soy

Whole grains:
Grains
Cereals
Popcorn

Starches in their whole form including:
Quinoa
Brown rice
Millet
Whole wheat
Oats
Barley

Nuts, seeds & oils:
Walnuts
Almonds
Cashews
Brazil nuts
Peanuts
Pumpkin seeds
Hemp seeds
Flax seeds
Chia seeds
Pumpkin seeds
Sunflower seeds
Olive oil
Soybean oil
Canola oil
Avocado oil
Sesame oil

SECTION 3
FUELING, BLOOD FLOW, INFLAMMATION, AND IMMUNITY

David Goldman, MS, RDN, CSSD, CSCS

Rebecca Soni, Plant-based Athlete
Multiple Olympic Gold & Silver, 2008 & 2012

David Goldman

Introduction

How Plants Stack up Against Animal Foods

There is clear consensus among reputable organizations that "the performance of, and recovery from, sporting activities are enhanced by well-chosen nutrition strategies."[1] These and other organizations, including the International Olympic Committee, underscore the value of scientifically grounded dietary guidelines that enable athletes to reduce their risk of injury and illness while training more effectively.[2] Since health is a prerequisite for a successful athletic career,[3] this section of the Playbook will address the connections between dietary choices and health, as well as exercise performance. Specifically, the contrasting relationships between foods of animal or plant origin and fueling, blood flow, inflammation, and immunity will be discussed in detail. The purpose of these educational materials is to extend the efforts of clinicians, coaches, and athletes in supporting dietary choices that augment training and recovery alike, setting the stage for competitions deluged with world records.

Fueling

Introduction

Nearly half of American college athletes surveyed were under the impression that protein fuels muscles or provides "immediate" energy.[4] Even during prolonged exercise however, protein acts as an auxiliary fuel source, contributing just 5-20% of energy requirements, while fat and carbohydrates are predominant fuels.[5] Fat supplies energy for exercise but can't generate it quickly enough to support high-intensity efforts. Carbohydrates then take center stage. According to a recent paper in the journal Nature Metabolism, "Carbohydrate is the fuel for high-intensity exercise."[6]

Diets Centered on Meat and Animal Products Provide Low-grade Fuel for Subpar Exercise Performance

As it stands, most athletes over-consume fat and protein while undereating carbohydrates. Accordingly, they frequently fail to meet dietary recommendations for optimal performance.[7-12] Emphasizing meat and animal products pushes their diets even further off kilter since these foods consist mostly of fat and protein while being particularly poor sources of carbohydrates.

Without sufficient carbohydrates, the capacity to build muscle diminishes. A recent meta-analysis including 13 randomized controlled trials quantified this effect, finding that people eating low-carbohydrate ketogenic diets lost an average of nearly three pounds of fat-free mass—including muscle—compared to those eating a more balanced diet.[13] Resistance training failed to protect against this loss.

David Welch, PhD, Plant Cell Biology
Avid Distance Runner

High-intensity performance also suffers from insufficient carbohydrates. While lay media outlets often make this topic seem controversial, the most recent joint position paper from the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine explains that, "Although there has been historical and recently revived interest in chronic adaptation to high-fat, low-carbohydrate diets, the present evidence suggests that enhanced rates of fat oxidation can only match exercise capacity/performance achieved by diets or strategies promoting high carbohydrate availability at moderate intensities, whereas the performance of exercise at the higher intensities is impaired."[14] In other words, fat and protein rich foods like meat, eggs, and cheese tend to displace dietary carbohydrates in the diets of athletes, and this can undermine muscle growth and high-intensity exercise performance.

AFTER SIX MONTHS ON THESE RESPECTIVE DIETS, RUGBY PLAYERS WHO DISPLACED CARBOHYDRATES WITH A HIGHER-PROTEIN DIET GAINED JUST A SINGLE POUND OF MUSCLE. THOSE EATING THE PLANT-BASED, CARBOHYDRATE-RICH MEDITERRANEAN DIET GAINED FIVE POUNDS OF MUSCLE.

Diets Centered on Plant-based Foods Supply Top-tier Fuel for High-quality Exercise Performance

Plant foods contain fat and protein too, but they differ from meat and animal foods in that they tend to be rich in carbohydrates. This makes them ideal sports nutrition staples. Diets built on a foundation of grains, beans, sweet potatoes, and other plants fosters effective carbohydrate storage in the form of liver and muscle glycogen.[15] Loading these tissues with the fuel they need supports gains in muscle mass and endurance, which are critical assets to competitive athletes.

When researchers compared the effects of a plant-based Mediterranean diet versus a high-protein diet centering more on animal foods, their findings flew in the face of what many would expect.[16] After six months on these respective diets, rugby players who displaced carbohydrates with a higher-protein diet gained just a single pound of muscle. Those eating the plant-based, carbohydrate rich Mediterranean diet gained five pounds of muscle.

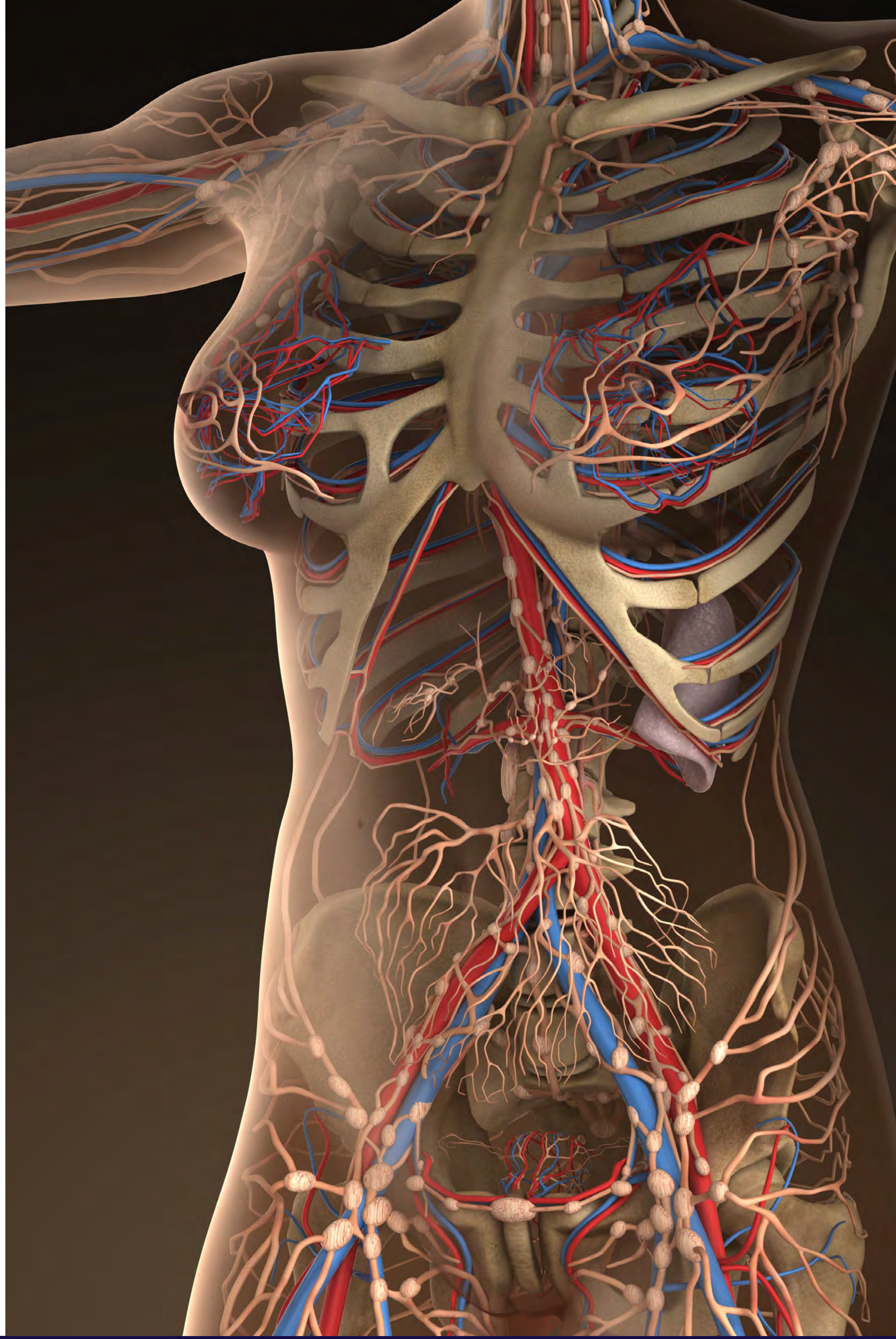
Research also demonstrates performance advantages in people eating vegan diets compared to those consuming meat and animal products. For example, a recent study published in the European Journal of Clinical Nutrition found superior aerobic capacity (measured as estimated VO2 max) in vegan versus omnivorous women as well as increased submaximal endurance time to exhaustion.[17] Research published three months later found that male runners adhering to a vegan diet also displayed greater VO2 max.[18] In both studies, the authors noted that the carbohydrate content of these diets was at least partially responsible for the differences in exercise performance.

WHETHER FUELING UP FOR MORE MUSCLE, BETTER EXERCISE PERFORMANCE, OR BETTER HEALTH, ANIMAL FOODS SABOTAGE OUR EFFORTS WHILE PLANT FOODS BOLSTER THEM.

Animal- Versus Plant-based Fueling Impacts Health in Opposite Directions

The way we fuel our bodies doesn't just affect exercise performance but health as well. Meat and metabolic damage go hand in hand. This is reflected by the fact that—compared to people who avoid meat—those who eat meat have more than twice the odds of developing Metabolic Syndrome, a cluster of conditions that set the stage for diabetes and heart disease.[19] The saturated fat and heme iron found in meat play an important role in this relationship,[20] but so does animal protein itself.[21]

Conversely, plant-based diets shield people from Metabolic syndrome.[21] Entirely plant-based diets are tethered to improvements in every single dimension of Metabolic Syndrome, providing benefits from multiple angles.[22] The fruits and vegetables they include provide protection,[20] as do other plant foods like beans and lentils.[23] Multiple components of these foods—like their antioxidant vitamins and phytochemicals—also provide metabolic benefits that can improve Metabolic Syndrome.[21,23]



Blood Flow

Introduction

Blood flow is critical during exercise. It delivers oxygen and nutrients to, and eliminates carbon dioxide and waste from, working muscles. Blood viscosity—or thickness—is highly consequential to blood flow and exercise performance,[1] as thick blood decreases the amount of oxygen that makes it to target tissues, worsening performance.[24] Thinner blood is therefore preferable, improving blood flow and supporting exercise performance.[25]

TWO HOURS AFTER PEOPLE ATE A MEAL RICH IN MEAT AND ANIMAL PRODUCTS, THEIR ARTERIES SUFFERED A 40% DROP IN THEIR ABILITY TO EXPAND.

Arterial flexibility is also important since stiff arteries impede blood flow while compliant and flexible arteries enhance blood flow. Food choices affect these factors which, in turn, influence blood flow and potentially exercise performance as well.[15]

Meals Built Around Meat and Animal Products Impede Blood Flow, Setting the Stage for Worse Exercise Performance

Research exploring the relationship between diet and blood quality found that people who eat meat have significantly thicker blood than people who avoid it.[26] Furthermore, just two hours after people ate a meal rich in meat and animal products, their arteries suffered a 40% drop in their ability to expand.[27]

This is largely due to the saturated fat commonly found in meat, which is linked to dysfunctional arteries.[25,26] People who eat meat also maintain elevated blood cholesterol levels,[27] which increase blood viscosity and worsen blood flow.[28] These cardiovascular and hematological profiles are not ideal for anyone, let alone athletes.

Meals Built From Plant Foods Promote Blood Flow, Setting the Stage for Better Exercise Performance

People eating plant-based diets have thinner blood and those who most consistently opt for plants instead of meat maintain the thinnest blood of all.[26] Similarly, plant-based meals don't compromise the arteries' ability to dilate, leaving them fully functional and conducive to optimal blood flow.[27] These effects stem from the nutrient profile of plants being low in saturated fat, devoid of cholesterol, and rich in fiber, phytosterols, phenolics, carotenoids, and multiple additional health-promoting phytonutrients that decrease the amount of cholesterol in the blood,[30] which is linked to blood viscosity[32] and the arteries' capacity to expand.[27] Superior blood flow is therefore yet another way by which plant-based diets may improve athletic performance.[33]

The Effects of Our Meals on Blood Flow Transcends Athletics, Influencing Disease and Health

Thick blood isn't just consequential for exercise. It also makes it harder for muscles to pull sugar from the blood, contributing to high blood sugar and Metabolic Syndrome while accelerating heart disease and increasing the risk of a life-threatening blood clot.[34]

Similarly, dysfunctional arteries that struggle to expand are implicated in high blood pressure, diabetes, heart disease, and heart failure.[37] Testing an artery's ability to dilate is such a sensitive tool that it can be used to detect and diagnose patients in the early stages of heart disease.[27] While constituents found in meat and animal products exacerbate these problems, plant-based diets have been shown to reverse this dysfunction, with research actually demonstrating the cardioprotective effects of plant-based eating.[35]

Inflammation

Introduction

Recovering from trauma, infection, or even exercise training involves an acute inflammatory response that's both necessary and productive for healing and adaptation. When inflammation becomes chronic however, it can inflict considerable damage and powerfully erode health.[36] Chronic inflammation that occurs throughout the body, or systemic inflammation, not only impairs exercise performance,[37] but it also accurately predicts both disability and death, even in otherwise seemingly healthy people.[36] Dietary choices play a significant role in elevating or lowering inflammatory markers[38] and accordingly detract from or contribute to both exercise performance and health.

Meat and Animal Products Trigger a Whole-body Inflammatory Response That Could Impair Exercise Performance

Meat and animal products have been shown to increase inflammatory markers quickly and powerfully. Four hours after eating a hamburger, healthy people experienced a ~70% rise in inflammatory measures.[39] The inflammatory effects of such foods have been largely attributed to the chemical contaminants they contain, including polycyclic aromatic hydrocarbons, heterocyclic amines, and advanced glycation end products.[40] Inflammatory processes can contribute significantly to muscle soreness following exercise,[41] and systemic inflammation resulting from a Western diet high in animal foods may impair physical performance.[37] Amplifying the inflammatory response by consuming animal foods therefore seems counterproductive to anyone seeking timely recovery and effective subsequent training sessions.

Plant-based Diets Decrease Inflammatory Markers, Potentially Translating to Significantly Better Exercise Performance

Plants are uniquely rich in antioxidants—compounds that eliminate free radicals and other potentially harmful molecules. In fact, the average plant food has 64 times the antioxidant content of animal foods.[42] Selecting antioxidant-rich foods is helpful for a number of reasons, not the least of which is their ability to significantly decrease measures of systemic inflammation.[43] This helps explain why four weeks on a diet high in animal protein led to a 46% increase in inflammatory markers, differing significantly from a plant-based diet which decreased inflammatory markers by 28%.[28]

It's not just one study. Meta-analysis of dozens of studies found that people eating plant-based diets maintain lower levels of inflammatory markers,[44] which scientists suggest may translate to improvements in exercise performance.[45] For example, when runners ate a plant-based, Mediterranean diet or Western diet, rich in animal foods, their 5K time trials were 6% faster after just four days eating the plant-based diet.[37] The researchers explained that the greater antioxidant content and potent anti-inflammatory effects of the plant-based diet contrasted with the pro-inflammatory Western diet, potentially contributing to the observed differences in endurance.

MEAT AND ANIMAL PRODUCTS HAVE BEEN SHOWN TO INCREASE INFLAMMATORY MARKERS QUICKLY AND POWERFULLY. FOUR HOURS AFTER EATING A HAMBURGER, HEALTHY PEOPLE EXPERIENCED A 70% RISE IN INFLAMMATORY MEASURES.

The Inflammatory or Anti-inflammatory Effects of Eating Styles Play Central Roles in Disease and Health

Persistent inflammation plays an important role in disease processes as well. Inflammation is not just a key factor in one or two diseases, either. Chronic systemic inflammation can promote the leading causes of disability and death worldwide including cardiovascular disease, cancer, diabetes, kidney disease, and autoimmune and neurodegenerative diseases among others.[46] Contrasting inflammatory profiles in people who eat or avoid meat likely explain the differing risks they experience.[47] For example, large-scale research finds that, compared to people who eat meat, those who avoid it cut their risk of developing colon cancer and type 2 diabetes in half in addition to living longer lives.[48] In other words, the pro-inflammatory effects of animal foods and the anti-inflammatory effects of plant foods further explain why plant-based dietary patterns are invaluable for improving life—both in quality and quantity.

Megan Duhamel, Plant-based Athlete
Multiple Olympic Gold & Silver, 2014 & 2018

Immunity

SINCE DIET STRONGLY INFLUENCES OUR DEFENSE SYSTEMS, SUPERIOR IMMUNOCOMPETENCE IS A PARTICULARLY IMPORTANT REASON FOR SERIOUS ATHLETES TO IMPROVE THEIR EATING HABITS.

Introduction

Athletes with heavy training and competition schedules are at increased risk of impaired immune function, largely due to the immunosuppressive effects of stress hormones like cortisol and adrenaline. Competitive athletes are therefore more susceptible to infections, especially upper respiratory tract infections.[49] Illness—particularly viral infections—can sideline athletes, making top competitors keen to avoid these disruptions to training and competition. Since diet strongly influences our defense systems, superior immunocompetence is a particularly important reason for serious athletes to improve their eating habits.[50]

Eating Meat is Linked to Worse Measures of Immune Function, Stacking the Odds Against a Healthy, Consistent Training Season

According to a recent meta-analysis, people whose diets include meat display unfavorable immune biomarkers like elevated total leukocytes,[44] which are white blood cells that increase in number when it's time to fight germs. Perhaps their bodies are mounting immune responses to their meals since data from the United States Food and Drug Administration reported that more than 10% of retail chicken is contaminated with Salmonella, nearly 40% of chicken is contaminated with Campylobacter, and about 75% of chicken is contaminated with E. Coli. Beef, pork, and turkey also show significant levels of contamination,[51] explaining why 70 million Americans get sick from food poisoning each year, and why meat and animal products are the most common causes of food poisoning in the United States, Canada, and Europe.[52]

Other factors are at play, too, since certain components of animal foods—like saturated fat, choline, cholesterol, and carnitine—can negatively impact immune function.[45] Furthermore, sufficient antioxidants are required for proper immune function and defense from infection[50] yet meat and animal foods are typically low in antioxidants.[42] For these and other reasons, it's clear that diets built around meat and animal products are unproductive for athletes looking to remain healthy enough to train and compete with consistency.

Plant-based Diets are Linked to Better Biomarkers of Immunity, Stacking the Odds in Favor of a Healthy, Productive Training Season

People who eat plant-based diets maintain favorable immune biomarkers,[41] including improved leukocyte levels, lymphocyte responsiveness, and natural killer cell functionality.[30] One reason for this finding is the array of phytonutrients found in whole plant foods that exert antioxidant effects and directly influence the immune system.[42] Plants actually contain thousands of these immune-enhancing nutrients, including carotenoids, glucosinolates, and flavonoids[37], which explains why people who eat more fruits and vegetables have an increased antibody response[51] and get fewer acute respiratory infections.[52] These benefits have led sports nutrition experts to conclude that "vegans and thus vegan athletes are superior in relation to regeneration and the immune system when compared to non-vegans, resulting from significantly lower inflammation, the stronger immune defense against bacteria and viruses, and the better antioxidant status due to the overall higher nutrient density of vegan diets."[30]

The Foods We Eat Can Help Protect Us From Many Diseases, Not the Least of Which is Covid-19

The contrasting relationships between animal and plant foods on immunity play out in a number of ways. Beyond getting fewer acute respiratory infections in general on a diet rich in fruits and vegetables,[55] plant-based eating patterns have been shown to protect people from chronic diseases as well. Their effects are powerful enough to lead a team of medical doctors and researchers to write that, "Of all the diets recommended over the last few decades to turn the tide of these chronic illnesses, the best but perhaps least common may be those that are plant-based."[56]

To share perhaps the most current example of the role that plant-based diets play in immunity, research published in June 2021 found that the diets of healthcare workers living in six different countries were significantly linked to their chances of moderate-to-severe cases of COVID-19.[57] Specifically, those who reported following low-carbohydrate, high-protein diets that are typically built on a foundation of meat and animal products had 286% greater odds of a moderate-to-severe case of COVID-19 compared to those eating plant-based diets. Compared to people following more conventional diets that include ordinary amounts of animal foods, those who reported eating plant-based diets had 73% lower odds of moderate-to-severe cases of COVID-19. The researchers concluded that "These dietary patterns may be considered for protection against severe COVID-19."

Recognizing the strong connection between immunity, exercise performance, and health, a paper published in Current Sports Medicine Reports encapsulates the big picture: "Based on the evidence in the literature that diets high in unrefined plant foods are associated with beneficial effects on overall health, lifespan, immune function, and cardiovascular health, such diets likely would promote improved athletic performance as well."[50]

SECTION 4
ATHLETES SEEKING A HEALTHY GUT FOR OPTIMAL PERFORMANCE

Angie Sadeghi, MD

Kendrick Farris, Plant-based Athlete
Olympian, 2008, US record holder

Angie Sadeghi

Introduction

For over a century, cow's milk has been touted as a healthy part of a balanced diet. Celebrity athletes pose sporting milk mustaches. Chocolate milk is promoted as an exercise recovery beverage. And the idea that milk builds strong bones and muscles is best exemplified by the advertising campaign; "Milk does a body good." All very effective marketing, but is it good science?

When we look at the evidence, cow's milk has serious negative effects on general health and is an underlying factor in numerous chronic diseases. But the most alarming truth about dairy, as it relates to an athletic audience, is that dairy impedes athletic performance—and it all starts in the gut. Microbiome dysbiosis is a chronic issue whose genesis can be closely linked to a diet rich in dairy products. And it is no wonder, as 68% of the world's population is lactose intolerant, with lactose being one of the sugars found in dairy products. There is a much higher incidence of lactose intolerance among people of African, Latin, and Asian descent, as well as other non-white minorities. Lactose intolerance can exacerbate congestion, stomach cramping, bloating, constipation, diarrhea, and unwanted skin rashes; all symptoms that can seriously negatively affect a great training session or a peak performance.

The following look at dairy's effect on the gut is based on a growing body of independent, peer-reviewed evidence about the negative effects of dairy consumption.

The gastrointestinal tract harbors 100 trillion organisms from mouth to anus. Combined, these organisms are commonly referred to as the microbiome and make up the largest organ in the body—containing 100 times more genetics than our own eukaryotic cells. Most of these organisms reside in the colon where they are involved with innumerable biochemical reactions. Based on the food one consumes, these reactions can promote health or disease. That being said, nutrition plays an essential role in athletic performance. Generally, in sports performance, we want to maintain adequate nutrition, a healthy weight, optimal protein (including branched-chain amino acids), control of markers of disease, proper levels of carbohydrates to fuel high-performance exercise, and sufficient energy intake. We want to do this, all while not impairing exercise by feeling too bloated.

STATISTICALLY SPEAKING OUT OF THE 13,000 ATHLETES WHO COMPETE AT THE SUMMER AND WINTER OLYMPIC GAMES, ABOUT 8,840 OF THEM WOULD HAVE VARYING DEGREES OF GASTROINTESTINAL PROBLEMS DURING THEIR TRAINING AND EVEN WHILE COMPETING FOR A MEDAL IF THEY CONSUME DAIRY.

Unfortunately, dietary recommendations for elite athletes are primarily based on a high-protein, low-fiber diet, which is associated with reduced microbiota diversity and functionality[1] (e.g., less synthesis of by-products such as short-chain fatty acids which play a pivotal role in skeletal muscle function). Since many elite athletes suffer from gastrointestinal conditions,[2] coaches should focus on making recommendations that meet the criteria at the macronutrient level, but also contribute to healthy digestion and microbiome diversity. As a gastroenterologist who specializes in gut health and fitness, I'm always surprised to see athletes who consume foods that may diminish their performance. The dairy industry heavily advertises cow's milk as the beverage of choice for athletes, but many coaches who promote chocolate milk and whey protein never review the actual science. Here is what the science has taught us.

Lactose Causes GI Upset and Fatigue

Lactose (milk sugar) is the main source of carbohydrates in breast milk (of any species) and is suited for infants who are uniquely adapted to lactose-based nutrition. Cow's milk contains approximately 12.5 g lactose in a typical serving size of 250mL (or one cup).[3] Digestion and absorption of lactose takes place in the small intestine by an enzyme along the brush border of villi in the small bowel, called lactase.[4] Diminished expression of this enzyme is common and known as lactase deficiency.[5] When a person who is lactase deficient consumes lactose, it will lead to lactose malabsorption which manifests as abdominal pain, bloating, constipation, or diarrhea.[4,5] The activity of lactase in the small intestine reaches a peak at the time of birth but is reduced in most populations during early childhood. The undigested lactose in the small intestine leads to trapping of water in the colon, causing significant diarrhea.[6]

Worldwide, most individuals have lactose intolerance.[4] A recent meta-analysis estimated the prevalence of lactose malabsorption worldwide at 68%.[7] Therefore, if they consume dairy, then statistically speaking out of the 13,000 athletes who compete at the Summer and Winter Olympic Games, about 8,840 of them would have varying degrees of gastrointestinal problems during their training and even while competing for a medal.

Many individuals develop symptoms of intolerance rather than malabsorption. These symptoms may include abdominal pain, borborygmi (rumbling tummy), and significant gas and bloating after lactose intake. The onset of these symptoms is strongly correlated to the appearance of hydrogen gas during breath tests which is seen in a condition called small intestinal bacterial overgrowth (SIBO) and IBS. So perhaps drinking cow's milk could be involved in the overgrowth of small intestinal bacteria seen in SIBO. Products of lactose fermentation by the colonic organisms may also trigger fatigue and neurological symptoms. A recent review of results from over 2,000 patients reported a high frequency of neurological symptoms such as tiredness and headache after lactose ingestion,[8] posing a significant problem for athletes in the face of completing or winning a competition.

Lactose Intolerance May Lead to Microbiome Dysbiosis and Irritable Bowel Syndrome

Undigested lactose travels through the gastrointestinal tract and is fermented in the colon, producing carbon dioxide, hydrogen gas, and methane by gas-producing microbes. However, does it lead to dysbiosis (a microbial imbalance) and/or irritable bowel syndrome?

The relationship of lactose intolerance and irritable bowel syndrome has been extensively studied in a South Chinese population with near 100 percent lactose intolerance based on genetic testing. A double-blind,

randomized, cross-over comparison of lactose tolerance at 10, 20, and 40g lactose was performed in IBS patients with diarrhea (IBS-D) and healthy controls. This study demonstrated a very strong correlation between the appearance of hydrogen gas in the breath and reports of bloating, pain, and other symptoms in patients with lactose intolerance. Symptoms of intestinal gas production were increased in patients with IBS-D.[9] Further research has demonstrated that pain of the inner organs and high levels of gas production on breath tests all increased the severity of abdominal symptoms after ingestion of 20g lactose,[10] an amount that may be found in about one and a half servings of milk.

Moreover, biopsies from the small intestine and colon have shown increased numbers of inflammatory cells in lactose-sensitive patients. The type of inflammatory cells shown to increase include mast cells (increase in response to allergies) and lymphocytes (white cells in response to infection and inflammation) in lactose-sensitive patients. Furthermore, studies have shown that lactose ingestion spurs the release of substances known as inflammatory cytokines, which are triggered by inflammation and used to recruit other inflammatory white cells.[11] The cause of irritable bowel syndrome remains elusive, but dairy products should be considered as a potential underlying promoter of IBS.

Implications for Athletes

As far as athletes are concerned, drinking cow's milk may create several problems:

1. Cow's milk consumption could cause a vicious cycle of inflammation, which could interfere with athletic performance.
2. Athletes who use cow's milk as a sports nutrition beverage risk abdominal discomfort, bloating/distension, gas, diarrhea, and/or constipation.
3. Athletes commonly report symptoms consistent with IBS[12] and dairy consumption can worsen such symptoms.[9,10]

Excessive Intake of Sulfate-producing Foods Can Potentially Damage the Gut

Significant amounts of sulfur-containing amino acids are found in cow's milk and cheese.[13] Consumption of large amounts of these foods may significantly increase sulfide production in the colon by the colonic bacteria.[14] Most of the bacteria live inside the colon in a symbiotic relationship with us humans as the host. Sulfate-producing bacteria are members of the normal colonic flora and they ferment the amino acids from dairy to produce hydrogen sulfide, which is toxic to human cells.[15]

Research found the elimination of milk and cheese from the diet of sufferers of ulcerative colitis (an inflammatory bowel disease which manifests as ulcers in the colon) results in substantial therapeutic benefit, suggesting that reducing the intake of sulfur-containing amino acids decreases colonic production of sulfide.[16] Indeed, sulfur-containing foods were positively associated with ulcerative colitis relapse in a 2015 review.[17]

A High-protein Beverage is Not Necessarily Healthy

Drinking milk for protein (or calcium) is like drinking soda for potassium. The studies show that athletes need to consume about 1.2 to 2.0 grams of protein per kilogram of lean body weight per day.[18-20] This is important regarding muscle regeneration and recovery. However, in excess, protein may cause harm. When a person eats more dietary protein than they are able to digest, some of it may escape digestion in the small bowel and enter the colon largely intact, where it is fermented by the colonic microflora. The resulting end products include branched-chain fatty acids (e.g., isovalerate, isobutyrate, and 2-methylbutyrate) and potentially harmful metabolites (ammonia, amines, phenols, sulfide, and indoles).[21-23] Ammonia reduces the lifespan of intestinal cells and is considered to be toxic to healthy cells—potentially promoting cancer growth.[24] The production of these toxic compounds is directly related to dietary protein intake,[24] a reduction of which can decrease the production of harmful by-products. In comparison to diets high in overall protein, diets high in animal protein have specific effects on intestinal microflora.[25-27] Ingestion of large amounts of animal protein does increase the activity of certain bacterial enzymes, which may result in increased release of potentially toxic metabolites in the bowel.[28]

The Fatigued Athlete

Fatigue management in an athlete's training is important for performance because adequate recovery allows athletes to train harder and more vigorously while avoiding injuries, and it all starts in the gut. Most coaches design their athletes' nutrition around how quickly they can recover, because effective nutrition and hydration are key strategies for optimizing recovery. The gastrointestinal tract plays an important role in the absorption of nutrients, but the normal absorptive capacity of healthy nutrients could be interrupted which negates their health benefits.

Research has shown that drinks such as beetroot juice—which is a rich source of antioxidants and high in nitrates—can improve athletic performance.[29] Nitrate is a chemical naturally occurring in certain foods, which our bodies convert to nitric oxide. Nitric oxide is a potent molecule that increases blood flow, improves lung function, and strengthens muscle contraction. Furthermore, beetroot juice aids in recovery by preserving muscle function and improving cardiorespiratory fitness.[29] In addition to its nitrates, beetroot contains antioxidants which may further benefit recovery by reducing oxidative stress and inflammation.[30]

There are other types of antioxidants including vitamin C, vitamin E, and beta-carotene—which like polyphenols[31] help repair cellular damage.[32] Polyphenols (of which 8,000 have been identified) are a class of phytonutrients that are found only in plant-based foods. Consumption of these foods is key in improving and expediting recovery in athletes.

On the other hand, studies have shown that cow's milk reduces the health benefits of antioxidant-rich foods by reducing the absorption of polyphenols and blocking the antioxidant effects.[33-35] In a study of cocoa and milk, the addition of milk reduced the antioxidant capacity of cocoa products by 30%.[35]

In another study where researchers tested antioxidant activity of blueberries in association with milk, when milk and blueberries were ingested together, there was a reduction in the antioxidant properties of blueberries and reduced nutrient absorption.[34] Research finds that the alpha-casein protein in milk binds to antioxidants and prevents their absorption.[35]

In conclusion, when it comes to optimizing nutrition for athletes, a milk beverage may have to take the back seat in favor of nutritious, antioxidant-rich food and drinks which can facilitate faster recovery.

Making the switch to a plant-based diet is easy, but it always helps to have support along the way. Section 5 includes selections from our *Plant-strong Toolbox* packed with resources to help your team succeed.

SECTION 5
IMPLEMENTATION TOOLS AND RESOURCES

Dotsie Bausch, Plant-based Olympian (Silver, 2012), Founder, Switch4Good
Jason Wrobel, CMC, Host, *How to Live to 100* (Cooking Channel), Author, *Eaternity*
Eric Sternlicht, PhD, Associate Professor, Department of Health Sciences, Chapman University, Author, *Fuel Up*

What to Eat

What to Expect

How to Learn More

"A well-established body of evidence and the world's leading health authorities have concluded that the dangers posed by animal foods are quite real, and that a diet centered around plants is optimal for human health and optimum performance."

Dr. James Loomis; team physician for the St. Louis Rams' Super Bowl team and the St. Louis Cardinals' World Series team

What to Eat

How to Put Together a Plant-based Meal

Use this basic mix-and-match tool to create nourishing, tasty meals to fulfill any athlete's protein, carbohydrate, and fat needs. Choose at least one food from each category to satisfy both macronutrient and micronutrient levels. Adjust serving size based on athletes' caloric needs.

1	2	3	4
Grains	**Greens**	**Cooked Beans**	**Flavor Bomb Superfoods**
Quinoa	Seaweed	Pinto	Tahini
Pasta	Kale	Black	Sauerkraut
Couscous	Spinach	Adzuki	Kimchi
Farro	Mixed greens	Garbanzo	Sriracha
Rice	Romaine	Kidney	Salsa
Whole wheat bread	Collard greens	Lentils	Avocado
Whole wheat tortilla	Bok Choy	Navy	Pickled onions
Amaranth	Broccoli	Black-eyed peas	Nuts & seeds
Oats	Brussels sprouts	Tofu	Fresh herbs
		Edamame	Nutritional yeast
		Tempeh	

Note: While beans provide the bulk of the protein, the foods in other categories also contain a significant amount of protein (e.g., quinoa, farro, and tahini) and supply a good amount of carbohydrates. When athletes focus less on protein and more on the overall makeup of the meal, they will optimize their diet by including key micronutrients and antioxidants to help them train and recover better than they could on a protein-heavy diet that's poor in carbohydrates, micronutrients, or antioxidants. Always cook legumes before consuming.

Sample Meals

These meals are good examples of what an athlete might eat throughout the course of a day. They are easy and quick to make, nourishing, and infinitely customizable to an athlete's tastes and the availability of ingredients.

Smoothie

Large handful of greens (try spinach or kale) with a small handful of frozen or fresh fruit, spoonful of nut butter or plant-based protein powder, plus a splash of non-dairy milk to achieve the preferred consistency.

Porridge

Grain cooked with non-dairy milk, topped with fruit, nuts or nut butter, and a dash of cinnamon.

Buddha Bowl / Big Salad

Leafy greens (romaine, spring mix, spinach, and/or kale), topped with fresh vegetables, cooked beans or tofu, grains, something pickled, and a nut-based dressing or vinaigrette.

Loaded Sweet Potato and Greens

Large roasted sweet potato, stuffed with grains and beans, drizzled with salsa or your favorite sauce. Served with a large side of steamed or roasted green veggies.

For a wide selection of plant-based recipes for every meal, click here: switch4good.org/food

Anti-inflammatory and Recovery Foods

Any form of exercise causes stress to your body, which then requires healing. The goal is for your body to adapt to the stress you've placed on it, thereby getting stronger/faster/better before the next workout.

It's important to know WHAT to eat and, more importantly, WHY the foods you consume are beneficial for your athletic performance and physical optimization. In this section, we are highlighting our top foods and their specific functional benefits to help you improve key metrics so you can perform at your best. We have identified four primary categories that are important for optimizing your performance:

1. **Inflammation Reduction**
2. **Rest & Recovery**
3. **Blood Flow & Circulation**
4. **Energy & Stamina**

You will learn how the **functional benefits of the foods** you eat directly impact specific aspects of your physical health. As well as learning which key micronutrients, vitamins, minerals, and antioxidants can improve your performance and assist in your recovery.

Why does this matter for your performance? Food is fuel for the human body. By mindfully and intentionally consuming the right foods with specific nutrients and their attendant functional benefits, you can utilize these foods as "high-octane" fuel to optimize your performance, maximize your energy, decrease your recovery time, and reduce inflammation.

Turmeric

Turmeric is a spice with a megadose of curcumin—a powerful anti-inflammatory. Turmeric reduces inflammation related to arthritis, diabetes, and other diseases. In fact, consuming 1 gram of curcumin daily combined with piperine from black pepper caused a significant decrease in the inflammatory marker CRP in people with metabolic syndrome. It's been shown that piperine can boost curcumin absorption by 2,000%.[1] Rule of thumb: when cooking with turmeric, always add a pinch of black pepper to optimize this spice's anti-inflammatory benefits.

Berries

Berries such as strawberries, blueberries, raspberries, and blackberries contain antioxidants called anthocyanins. These compounds have anti-inflammatory effects that may reduce your risk of disease. In one study, adults with excess weight who ate strawberries had lower levels of certain inflammatory markers associated with heart disease.[2]

Broccoli

Broccoli is rich in sulforaphane, an antioxidant that fights inflammation by reducing your levels of cytokines and NF-kB, which drive inflammation.[3]

Avocados

Avocados contain a compound that may reduce inflammation in young skin cells. In one study, when people consumed a slice of avocado with a hamburger, they had lower levels of the inflammatory markers NF-kB and IL-6, compared with participants who ate the hamburger alone.[4]

Green Tea

Green tea contains a substance called epigallocatechin-3-gallate (EGCG). EGCG inhibits inflammation by reducing pro-inflammatory cytokine production and damage to the fatty acids in your cells.[5] Green tea's high EGCG content reduces inflammation and safeguards your cells from damage that can lead to disease.

Tart Cherries

Tart cherries contain high amounts of melatonin which can promote sleepiness. In a research study, adults with insomnia drank 8 ounces (240 ml) of tart cherry juice twice a day for 2 weeks. They slept 84 minutes longer and reported better sleep quality compared to when they didn't drink the juice.[6]

Chamomile Tea

Chamomile tea contains apigenin—an antioxidant that binds to certain receptors in your brain that may promote sleepiness and reduce insomnia. One 2011 study in 34 adults found those who consumed 270 mg of chamomile extract twice daily for 28 days fell asleep 15 minutes faster and experienced less nighttime wakening compared to those who didn't consume the extract.[7]

Walnuts

Walnuts improve sleep quality due to their high melatonin content. The fatty acid makeup of walnuts may also contribute to better sleep. They provide alpha-linolenic acid (ALA), an omega-3 fatty acid that's converted to DHA in the body. DHA has been shown to increase serotonin production.[8]

Almonds

Almonds also contain a significant amount of melatonin and may boost sleep quality. Almonds are also an excellent source of magnesium. High magnesium amounts may promote sleep by helping to reduce the levels of cortisol (a stress hormone), which is known to interrupt sleep.[9]

Bananas

Bananas are rich in sleep-promoting nutrients like magnesium, tryptophan, vitamin B6, carbs, and potassium—all of which have been linked to improved sleep. Studies show that supplementing with 500 mg of magnesium daily may increase melatonin production and reduce cortisol levels.[9] Evidence has linked tryptophan-containing foods with improved sleep, including increased sleep time and efficiency, less difficulty falling asleep, and less waking at night.[10] Tryptophan improves sleep quality because it's converted into serotonin once it enters the brain. Potassium may also improve sleep quality by reducing muscle cramping.

Cinnamon

Cinnamon, a traditional warming spice, has been shown to increase blood flow. In research studies, cinnamon improved blood vessel dilation and blood flow in the coronary artery, which supplies blood to the heart.[11] Additional research shows that cinnamon can effectively reduce blood pressure in humans by relaxing blood vessels and thus improving circulation.[12]

Garlic

Garlic's sulfur compounds (including allicin) can increase tissue blood flow and lower blood pressure by relaxing blood vessels. Diets high in garlic are associated with better flow-mediated vasodilation (FMD), an indicator of blood flow efficiency. In a study of 42 people with coronary artery disease, those who consumed garlic powder tablets containing 1,200 mg of allicin twice daily for three months experienced a 50% improvement in blood flow through the upper arm artery compared to a placebo group.[13]

Beets

Beets are high in nitrates which may boost performance by improving oxygen flow in muscle tissue, stimulating blood flow, and increasing nitric oxide levels.[14]

Citrus Fruits

Citrus fruits like oranges, lemons, and grapefruit are packed with antioxidants including flavonoids. Consuming flavonoid-rich citrus fruits may decrease inflammation in your body, which can reduce blood pressure and stiffness in your arteries while improving blood flow and nitric oxide production. In a study in 31 people, those who drank 17 ounces (500 ml) of blood orange juice per day for one week had significant improvements in artery dilation and large reductions in markers of inflammation such as IL-6 and CRP compared to a control group.[15]

Leafy Greens

Leafy greens like spinach and collard greens, are high in nitrates which your body converts into nitric oxide—a potent vasodilator. Eating nitrate-rich foods may help improve circulation by dilating blood vessels, allowing your blood to flow more easily. In a 27-person study, those consuming high-nitrate (845 mg) spinach daily for seven days experienced significant improvements in blood pressure and blood flow compared to a control group.[16] What's more, research has observed that people following a traditional Japanese diet high in nitrate-rich vegetables like Chinese cabbage have lower blood pressure and a significantly decreased risk of heart disease than those who consume a typical Western diet.[17]

Energy and Stamina

Chia Seeds

Chia seeds provide essential fatty acids (omega-3 and omega-6) shown to enhance sleep quality, boost brain power, and combat inflammation, which keeps your body feeling fresh. Coupled with high levels of protein and fiber—which keep blood sugar stable (no afternoon sugar crashes)—chia seeds provide nutrients to keep the body functioning optimally.

Matcha

Matcha contains about 60 mg of caffeine per serving and the amino acid L-theanine. When coupled with caffeine, L-theanine helps to slow the entrance of caffeine molecules into the bloodstream. This means that instead of getting a quick jolt of energy followed by a crash, matcha green tea drinkers experience a day-long energy boost.

Sweet Potatoes

Sweet potatoes have a great balance of carbs, fiber, protein, and micronutrients to fuel athletes. One sweet potato provides about 100 calories and 25 grams of carbohydrates. Carbohydrates can be used immediately for a workout or stored in the liver and muscles for future use. The stored energy is called glycogen and is depleted as you work out. Having adequate glycogen stores helps prevent the body from breaking down protein and muscle to provide energy.

Quinoa

Quinoa contains a high combination of amino acids and slow-releasing carbohydrates that help gradually release energy for a long period of time. Quinoa is also high in riboflavin (vitamin B2) and manganese. Riboflavin improves energy metabolism within brain and muscle cells. Manganese helps to prevent damage of mitochondria during energy production as well as protects red blood cells from injury by free radicals.

Athlete Power Plate

The foods we use to fuel our performance should nourish our entire body—with no uncomfortable side effects. Athletes should work with their sports dietitian and consult this plate to create an eating plan that maximizes performance based on specific caloric needs.

Food for Thought

- The average plant has 64X more antioxidant content than animal foods. [18]
- Ounce for ounce, hemp seeds contain more protein than meat.[19]
- Superfood boosts: ground flax, nori, turmeric, cloves, cinnamon, ginger, green tea.
- A whole-food source is a food that is not packaged, bottled, processed, or refined.

Download your FREE Athlete Power Plate here: https://switch4good.org/athletes-hub/

The Macronutrients

All whole-plant foods have a mixture of carbohydrate, protein, and fat. Some macronutrients are found in greater amounts in certain foods.

Carbohydrate-rich Foods:

- Brown rice pasta, quinoa pasta, black bean pasta, chickpea pasta, whole-wheat pasta
- Black & brown rice, millet, farro, quinoa, bulgur, barley
- Potatoes & sweet potatoes
- Oats
- Sprouted grain bread, whole-grain bread
- Fruit: bananas, raspberries, blackberries, grapes, blueberries, apples, oranges, mangos, strawberries, melons, cherries, pomegranate, pineapple, jackfruit, tomatoes
- Vegetables: broccoli, spinach, kale, bok choy, beet & mustard greens, cauliflower, eggplant, peppers, Brussels sprouts, squashes, asparagus, carrots, zucchini, cabbage, arugula, leafy greens

Protein-rich Foods:

- Cooked legumes: black, navy, garbanzo, kidney, cannellini, and pinto beans, peas, lentils, edamame, and peanuts
- Tofu, tempeh, seitan
- Seeds: flax, chia, pumpkin, hemp, sesame

Fat-rich Foods:

- Nut and seed butters: peanut, cashew, almond, sunflower, tahini
- Avocados, olives
- Olive oil, pumpkin seed oil, avocado oil
- Nuts: almonds, walnuts, cashews, macadamia, hazelnuts, pine nuts, Brazil nuts, pistachios

Superfood Boosts

- Ground flax, nori, turmeric, cloves, cinnamon, ginger, green tea

Snacks and Travel Foods

Athletes often need to supplement meals with snacks either pre- or post- workout to obtain their caloric and nutritional needs. The foods below provide balanced carbohydrates, protein, and fats in addition to an assortment of essential micronutrients and antioxidants. All are convenient, portable, and widely available.

Hummus and Vegetable Sticks
Serving: ¼ cup hummus, 2 carrots, 1 celery stick
Nutrition: 205 calories, 26 g carb, 6 g protein, 5 g fat

Shelf-stable Soy Milk
Serving: 8oz
Nutrition: 170 calories, 25 g carb, 8 g protein, 4.5 g fat (based on Silk chocolate soy milk)

Overnight Oats (homemade or packaged)
Serving: ½ cup oats made with 1 cup unsweetened soy milk
Nutrition: 230 calories, 30 g carb, 12 g protein, 7 g fat

Banana with Nut or Seed Butter
Serving: 1 large banana, 2 tablespoons nut or seed butter
Nutrition: 320 calories, 36 g carb, 9.5 g protein, 16 g fat

Dates with Nut or Seed Butter
Serving: 2 dates, 2 tablespoons of nut or seed butter
Nutrition: 310 calories, 37 g carb, 9 g protein, 16 g fat

Nut, Seed, and Dried Fruit Mix
Serving: ¼ cup
Nutrition: 210 calories, 18 g carb, 7 g protein, 13 g fat

Plant-based Sports Bar
Nutrition: 300 calories, 27 g carb, 20 g protein, 11 g fat (based on Vega Sport Protein Bar)

Baked Sweet Potato
Serving: 1 medium sweet potato with 2 tablespoons tahini or nut/seed butter
Nutrition: 300 calories, 28 g carb, 10 g protein, 16 g fat

Granola and Plant-based Milk
Serving: ½ cup granola with 1 cup soy or pea milk
Nutrition: 310 calories, 30 g carb, 12 g protein, 15 g fat

Edamame
Serving: 1 cup, cooked and shelled
Nutrition: 190 calories, 14 g carb, 19 g protein, 8 g fat

Fruit and Nut Sandwich
Serving: 2 slices whole wheat bread, 1 banana, 1 tablespoon of nut butter
Nutrition: 410 calories, 69 g carb, 13 g protein, 8 g fat

Veggie Sandwich
Serving: 2 slices whole wheat bread, 2 tablespoons hummus, ½ cucumber, sliced
Nutrition: 290 calories, 48 g carb, 11 g protein, 9 g fat

Three-day Meal Plan for Adult Male Vegan Team Sport Athlete (80 kg) by Nanci Guest, PhD, RD, CSCS

Nutritional Content (across 3 days) for nutrients of concern: 613 g protein, 124 mg iron (non-heme), 7000 mg calcium, 18 g ALA, 75 mg zinc, and 18.7 µg vitamin B12. This menu has been created to show that a 100% plant-based vegan diet is a viable option for a high-performance athlete that is seeking a highly palatable nutrient-balanced sports nutrition meal plan. This detailed three-day meal plan provides variety while also meeting or exceeding all macro- and micronutrient requirements, with emphasis on those nutrients in need of consideration when excluding animal-sourced foods from the diet.

Sample Menu Day 1: Adult male training 12-15 hours per week, muscle mass maintenance

Menu Item[1]	Protein	Iron	Calcium	ALA[2]	Zinc
Nutritional Goal	1.6 g/kg =128 g	RDA = 14 mg[3]	RDA = 1,000 mg	AI = 1.6 g	RDA = 17 mg[4]
Actual Meal Plan Content with 5.8 µg vitamin B12 from fortified foods[5]	186 g	35 mg	2,477 mg	3.0 g	25 mg
7:00am WAKE-UP					
7:15am BREAKFAST					
PEANUT BUTTER, FRUIT & TOAST					
1 cup grapes or cherries	1 g	0.5 mg	15 mg	-	0.1 mg
2 slices ancient grains bread, toasted (75 g)	8 g	2 mg	75 mg	0.5 g	1.3 mg
3 tbsp all-fruit jam or ¼ cup crushed berries	-	-	-	-	-
3 tbsp almond butter	10 g	1.8 mg	165 mg	-	1.5 mg
1.5 cups fortified vanilla plant milk[6]	12 g	-	660 mg	-	-
9:00-11:00am SPORT PRACTICE					

Menu Item	Protein	Iron	Calcium	ALA	Zinc
10:00am MID-PRACTICE SNACK					
HOMEMADE ICED-WATERMELON SPORTS DRINK					
2 cups watermelon	2 g	0.8 mg	21 mg	-	0.3 mg
Pinch of salt, 3 cups water, 1 cup ice: mixed in blender	-	-	-	-	-
4 dates, Medjool (96 g)	1.7 g	0.8 mg	61 mg	-	0.4 mg
11:00am POST-WORKOUT SHAKE[7]					
MIXED BERRY PROTEIN SHAKE TOPPED WITH CHIA[8]					
1 scoop plant-based protein powder (40 g)	27 g	-	-	-	-
1 cup soy milk	7 g	1 mg	300 mg	0.1 g	0.5 mg
1 banana	1 g	0.25 mg	5 mg	-	0.15 mg
1 tbsp chia seeds (9 g)	1.6 g	0.5 mg	23 mg	-	0.5 mg

Menu Item	Protein	Iron	Calcium	ALA	Zinc
1:00pm LUNCH					
THE VEGAN MEXICAN CLASSIC WRAP					
1 whole wheat tortilla, large (71 g)	7 g	1.8 mg	173 mg	-	1.3 mg
¾ cup cooked brown rice (146 g)	4 g	0.8 mg	4.4 mg	-	1 mg
½ cup cooked black beans (130 g)	6 g	2 mg	60 mg	0.1 g	3 mg
½ cup corn (75 g)	2.5 g	0.5 mg	1.5 mg	-	0.5 mg
½ avocado (100 g)	2 g	0.5 mg	12 mg	0.1 g	0.6 mg
½ cup homemade salsa	-	0.5 mg	16 mg	-	-
½ tbsp ground flaxseed (4 g)	0.6 g	0.2 mg	9 mg	0.8 g	0.1 mg
¼ cup homemade cashew-based vegan sour cream (¼ cup cashews)[9]	5 g	2 mg	15 mg	-	2 mg
1/3 cup almonds, salted	10 g	1.8 mg	130 mg	0.1 g	1.6 mg
3:00pm PRE-WORKOUT SNACK					
1 medium-sized baked sweet potato (150 g) topped with vegan ranch dressing	2 g	1 mg	39 mg	0.2 g	0.3 mg

4:00-5:00pm STRENGTH & CONDITIONING SESSION

Menu Item	Protein	Iron	Calcium	ALA	Zinc
5:00pm POST-WORKOUT SHAKE					
BERRY COCONUT SMOOTHIE (blended, with creatine)					
1 cup mixed berries, frozen or fresh	1 g	0.5 mg	20 mg	-	0.5 mg
1 scoop creatine monohydrate powder (3 g)[10]	-	-	-	-	-
¼ cup coconut yogurt[11]	1 g	0.4 mg	-	-	-
½ cup fortified plant-milk	4 g	-	220 mg	-	-
1 tsp vanilla extract	-	-	-	-	-
1 cup spicy roasted chickpeas (on side)	15g	4 mg	100 mg	-	2.5 mg

Menu Item	Protein	Iron	Calcium	ALA	Zinc
7:00pm DINNER					
SESAME STIR-FRIED TOFU & VEGGIES OVER RICE					
1.5 cups cooked brown rice	7.5 g	1.4 mg	30 mg	-	1.8 mg
1 cup mushrooms, cooked (57 g)	2 g	-	-	-	1 mg
½ cup firm tofu, seasoned, cubed (126 g)	10 g	1.5 mg	216 mg	-	-
½ cup green peas, cooked (80 g)	4 g	1.2 mg	21 mg	-	0.8 mg
1 tsp sesame seeds (3 g)	0.6 g	0.2 mg	-	-	0.2 mg
1 tbsp olive oil	-	-	-	0.1 g	-
6 spears oven-roasted asparagus, seasoned (96 g)	2 g	2 mg	24 mg	-	0.5 mg

Menu Item	Protein	Iron	Calcium	ALA	Zinc
10:00pm BEDTIME SNACK					
4 recovery bites[12] (see Appendix on page 88 for recipe)	11.4 g	3.1 mg	60 mg	1 g	2.9 mg
½ scoop PB protein powder (blend into 1 cup coconut yogurt)[13]	17 g	1.8 mg	-	-	-

11:00pm SLEEP

Sample Menu Day 2: Adult male training 12-15 hours per week, muscle mass maintenance

Menu Item	Protein	Iron	Calcium	ALA	Zinc
Nutritional Goal	1.6 g/kg =128 g	RDA = 14 mg[14]	RDA = 1,000 mg	AI = 1.6 g	RDA = 17 mg[15]
Actual Meal Plan Content with 6.7 µg vitamin B12 from fortified foods[16]	230 g	54 mg	2,278 mg	8.8 g	27 mg
7:00am WAKE-UP					
7:15am BREAKFAST					
SEEDS AND BERRIES PROTEIN OATMEAL					
1 cup soy milk	7 g	1 mg	300 mg	0.1 g	0.5 mg
1.5 cups oatmeal, cooked (300 g)	7 g	2 mg	36 mg	0.1 g	1.9 mg
2 tbsp ground flaxseed (14 g)	2.6 g	0.8 mg	35 mg	3.2 g	0.6 mg
1 tbsp hemp hearts (10 g)	2 g	0.8 mg	7 mg	1 g	1 mg
1 tbsp pumpkin seeds	3 g	0.8 mg	5 mg	-	0.6 mg
1 cup blueberries	1 g	0.5 mg	9 mg	-	0.3 mg
9:00-11:00am SPORT PRACTICE					
10:00am MID-PRACTICE SNACK					
HOMEMADE ICED-WATERMELON SPORTS DRINK					
2 cups watermelon	2 g	0.8 mg	21 mg	-	0.4 mg
Pinch of salt, 3 cups water, 1 cup ice: mixed in blender	-	-	-	-	-
Handful of raisins (25 g)	1 g	0.4 mg	15 mg	-	0.1 mg

Menu Item	Protein	Iron	Calcium	ALA	Zinc
11:00am POST-WORKOUT SHAKE					
STRAWBERRY BANANA PROTEIN SHAKE					
1 scoop plant-based protein powder (40 g)	27 g	-	-	-	-
1 cup soy milk	7 g	1 mg	300 mg	0.1 g	0.5 mg
1 banana	1 g	0.25 mg	5 mg	-	0.15 mg
1 cup strawberries	1 g	1.7 mg	35 mg	-	0.3 mg
½ cup ice	-	-	-	-	-
1 oz pecans (on side)	2.5 g	0.7 mg	20 mg	0.3 g	1.2 mg
1:00pm LUNCH					
SPICY BLACK BEAN & CORN SALAD					
½ cup cooked black beans	8 g	1.8 mg	30 mg	0.1 g	1 mg
½ cup corn, cooked (75 g)	5 g	0.7 mg	3 mg	-	0.7 mg
1 tomato (chopped)	1 g	0.4 mg	12 mg	-	0.2 mg
¼ onion (chopped)	0.4 g	-	7 mg	-	-
1 bell pepper (120 g)	2 g	0.8 mg	21 mg	-	4 mg
½ avocado (100 g)	2 g	0.5 mg	12 mg	0.1 g	6 mg
1 tbsp olive oil	-	-	-	0.1 g	-
Homemade spicy vinaigrette dressing[17]	-	-	-	-	-

Menu Item	Protein	Iron	Calcium	ALA	Zinc
HIGH PROTEIN TRAIL MIX[18] (triple the recipe and consume over 3-4 days)					
½ cup cinnamon-roasted chickpeas	15 g	4 mg	100 mg	-	2.5 mg
1 oz cooked fava beans (28 g)	7 g	1.8 mg	29 mg	-	0.9 mg
1 oz pumpkin seeds (28 g)	10 g	3 mg	20 mg	-	2.5 mg
4 slices dried apricot, unsweetened	0.8 g	0.8 mg	16 mg	-	0.1 mg
1.5 oz raisins (43 g)	1.4 g	0.7 mg	27 mg	-	0.1 mg
1 oz pistachio nuts, salted	5.7 g	1.1 mg	30 mg	0.1 g	0.6 mg
3:00pm PRE-WORKOUT SNACK					
1 large whole wheat raisin bagel (130 g)	12.5 g	3.5 mg	131 mg	0.1 g	1.3 mg
2 tbsp almond butter	5.5 g	1.5 mg	110 mg	-	1 mg
4:00-5:00pm STRENGTH & CONDITIONING					
5:00pm POST-WORKOUT SHAKE					
APPLE PIE PROTEIN SHAKE					
½ block firm tofu (170 g)	9 g	3 mg	100 mg	-	-
1 apple, cored (200 g)	0.5 g	0.2 mg	11 mg	-	0.1 mg
1 scoop creatine monohydrate powder (3 g)	-	-	-	-	-
½ tsp cinnamon	-	-	-	-	-
¼ cup walnuts (30 g)	3 g	-	20 mg	1.8 g	0.6 mg
1 cup fortified vanilla plant milk[19]	8 g	-	440 mg	-	-
1 tsp vanilla extract	-	-	-	-	-

Menu Item	Protein	Iron	Calcium	ALA	Zinc
7:00pm DINNER					
TOMATO & LENTILS OVER EDAMAME PASTA					
2 oz edamame spaghetti	22 g	6.3 mg	120 mg	-	-
1 cup cherry tomatoes, chopped (149 g)	1 g	0.4 mg	15 mg	-	0.3 mg
1 cup lentils, boiled (198 g)	18 g	6.6 mg	38 mg	0.7 g	2.5 mg
1 cup onion, chopped	1.8 g	0.3 mg	37 mg	-	0.3 mg
3 tbsp olive oil	-	-	-	0.3 g	-
Homemade sauce, topped with herbs	-	-	-	-	-
10:00pm SNACK					
1 cup plant-based high-protein ice cream[20]	10 g	1.6 mg	40 mg	-	-
4 recovery bites[21] (see Appendix on page 88 for recipe)	11.4 g	1.3 mg	60 mg	1.04 g	2.9 mg
1 oz almonds (about 24)	6 g	1.5 mg	60 mg	-	0.9 mg
11:00pm BEDTIME					

Menu Item	Protein	Iron	Calcium	ALA	Zinc
Nutritional Goal	1.6 g/kg =128 g	RDA = 14 mg[22]	RDA = 1,000 mg	AI = 1.6 g	RDA = 17 mg[23]
Actual Meal Plan Content with 6.2 µg vitamin B12 from fortified foods[24]	198 g	35.3 mg	2,210 mg	6.2 g	23 mg
7:00am WAKE-UP					
7:15am BREAKFAST					
1.5 cups calcium-fortified orange juice	3 g	-	525 mg	-	-
1 cup plant-based scrambled eggs[25]	25 g	3.5 mg	100 mg	- [26]	-
4 strips plant-based bacon (32 g)[27]	4 g	0.8 mg	-	- [28]	0.2 mg
2 slices ancient grains bread, toasted (75 g)	8 g	2 mg	75 mg	0.5 g	1.3 mg
1 tbsp non-trans fat margarine (14 g)	-	-	2 mg	0.3 g	-
9:00-11:00am SPORT PRACTICE					
10:00am MID-PRACTICE SNACK					
DRIED FRUIT MEDLEY					
1.5 oz raisins	1.4 g	0.7 mg	27 mg	-	0.1 mg
3 dates, Medjool (72 g)	1.2 g	0.6 mg	45 mg	-	0.3 mg
4 slices dried apricot unsweetened	0.8 g	0.8 mg	16 mg	-	0.1 mg
4 slices dried mango	0.8 g	-	-	-	0.1 mg

Menu Item	Protein	Iron	Calcium	ALA	Zinc
11:00am POST-WORKOUT SHAKE					
BANANA NUT PROTEIN SHAKE					
1 scoop plant-based protein powder (40 g)	27 g	-	-	-	-
1 banana	1 g	0.25 mg	5 mg	-	0.1 mg
1 tbsp peanut butter (16 g)	3.5 g	0.2 mg	7.8 mg	-	0.4 mg
1 cup soy milk	7 g	1 mg	300 mg	0.12 g	0.5 mg
1:00pm LUNCH					
FRESH QUINOA ARUGULA SALAD WITH LEMON VINAIGRETTE					
1 cup arugula (20 g)	0.5 g	0.3 mg	32 mg	0.2 g	0.09 mg
1 cup cooked quinoa (185 g)	8 g	1 mg	32 mg	-	2 mg
½ cup cooked kidney beans (100 g)	5 g	1 mg	34 mg	0.1 g	0.5 mg
½ cup cooked lentils (100 g)	9 g	3.3 mg	19 mg	-	1.2 mg
1 tbsp capers	-	-	-	-	-
½ tbsp ground flaxseed (4 g)	0.6 g	0.2 mg	9 mg	0.8 g	0.1 mg
Homemade vinaigrette dressing[29]	-	-	-	-	-
Vegan cheese pizza[30] (112 g)	3 g	2 mg	40 mg	-	-

Menu Item	Protein	Iron		ALA	Zinc
3:00pm PRE-WORKOUT SNACK					
TORTILLA CHIPS WITH BEANS & SALSA					
½ cup cooked black beans	8 g	1.8 mg	30 mg	0.1 g	1 mg
½ cup homemade salsa	-	0.5 mg	16 mg	-	-
15-20 multigrain baked tortilla chips	3 g	0.4 mg	45 mg	-	0.3 mg
4:00-5:00pm STRENGTH & CONDITIONING					
5:00pm POST-WORKOUT SHAKE					
PISTACHIO SPINACH SMOOTHIE (blended, with creatine monohydrate)					
1 scoop creatine powder (3 g)	-	-	-	-	-
2 tbsp shelled pistachios	3 g	0.5 mg	15 mg	0.04 g	0.3 mg
1 cup spinach (25 g)	0.7 g	0.7 mg	25 mg	0.04 g-	0.1 mg
1 cup fortified vanilla plant milk[31]	8 g	-	440 mg	-	-
Handful ice	-	-	-	-	-
7:00pm DINNER					
CLASSIC VEGAN CHEESEBURGER					
1 whole grain burger bun	4 g	1 mg	40 mg	-	-
1 plant-based patty[32] (113 g)	20 g	4 mg	120 mg	-	8 mg
1 slice lettuce	-	-	-	-	-
1 slice dairy-free cheddar	-	-	-	-	-
1 slice tomato	-	-	-	-	-
1 tbsp mayonnaise	-	-	-	0.74 g	-

Menu Item	Protein	Iron	Calcium	ALA	Zinc
SWEET POTATO FRIES					
1 medium-sized sweet potato (150 g)	2 g	1 mg	39 mg	0.2 g	0.3 mg
1 tbsp olive oil, seasoned with cayenne and salt	-	-	-	0.1 g	-
SIDE KALE SALAD WITH POMEGRANATE & HEMP SEEDS					
1 cup kale	0.8 g	0.4 mg	64 mg	0.1 g	0.1 mg
2 tbsp hemp seeds (20 g)	4 g	1.6 mg	14 mg	2 g	2 mg
1 tbsp pomegranate seeds	0.5 g	-	3 mg	-	0.1 mg
1 tbsp olive oil	-	-	-	0.1 g	-
Homemade dressing[33]	-	-	-	-	-
10:00pm SNACK					
VEGAN COCONUT BERRY YOGURT BOWL[34]					
1 cup coconut yogurt[35]	4 g	1.8 mg	-	-	-
¾ scoop plant-based protein powder	20 g	-	-	-	-
1 cup blackberries (150 g)	2 g	1 mg	40 mg	-	0.8 mg
1 tbsp chia seeds (9 g)	1.6 g	0.5 mg	23 mg	-	0.5 mg
1 tbsp hemp seeds	2 g	0.8 mg	7 mg	1 g	1 mg
Handful of almonds (8)	2 g	0.5 mg	20 mg	-	0.3 mg
11:00pm BEDTIME					

Appendix

Recovery Bites (12)	Protein	Iron	Calcium	ALA	Zinc
¼ cup sunflower seeds, without shell (36 g)	7 g	1.1 mg	25 mg	0.01 g	1.4 mg
¼ cup pumpkin seeds, without shell (36 g)	11 g	2.8 mg	18.7 mg	0.1 g	2.5 mg
⅓ cup oats	3.3 g	1.1 mg	14 mg	0.02 g	1 mg
5 dates, Medjool	2 g	1 mg	75 mg	-	0.5 mg
2 tbsp goji berries	2 g	1 mg	30 mg	-	0.5 mg
¼ cup hemp seeds (28 g)	9 g	2.3 mg	20 mg	3 g	3 mg
Total	34.3 g	9.3 mg	182.7 mg	3.1 g	8.9 mg
Per 4 bites	11.4 g	3.1 mg	60.9 mg	1.04 g	2.9 mg

Nutritional Boost Add-Ons

- For an extra 6 g protein & 20 mg calcium: 4 tbsp hummus & vegetables
- For an extra 4 g protein & 0.5 mg iron: handful of wasabi peas
- For an extra 19 g protein & 2.3 mg zinc: 1 cup of edamame
- For an extra 11 g protein: 1.5 oz (42 g) roasted fava beans and peas can be added to salads and trail-mixes
- For an extra 11 g protein: 1/3 cup (52 g) almonds can be added to salads and trail-mixes
- For an extra 20 g protein, 3.8 mg iron, & 735 mg calcium: 1.5 cup high-protein plant-based drink

Notes

1. Nutritional facts sourced from USDA, Food Data Central, 2021
2. Alpha-linolenic acid
3. The recommended dietary allowance (RDA) for iron is 1.8 times higher for vegans and vegetarians than for omnivores
4. The RDA for zinc is 1.5 times higher for vegans and vegetarians than for omnivores
5. Fortified vanilla plant milk and soymilk
6. Based on Ripple pea-based milk (vanilla)
7. It is recommended that athletes invest in a good-quality blender for multi-ingredient protein shakes and smoothies
8. If no blender and on-the-go, mix protein powder with chilled plant milk and instead add chia seeds to today's lunch wrap
9. Also requires water, lemon juice, apple cider vinegar, sea salt, and Dijon mustard
10. If applicable to athlete's sport, 0.33 scoop (1.5 g) of beta-alanine powder is also recommended
11. Based on COYO probiotic coconut milk yogurt, available in US, UK, and Australia
12. Sunflower seeds, pumpkin seeds, oats, dates, goji berries, hemp seeds
13. Based on COYO probiotic coconut milk yogurt, available in US, UK, and Australia
14. The RDA for iron is 1.8 times higher for vegans and vegetarians than for omnivores
15. The RDA for zinc is 1.5 times higher for vegans and vegetarians than for omnivores
16. Soymilk and fortified vanilla plant milk
17. Also requires vinegar, Dijon mustard, maple syrup, garlic, and salt and pepper
18. Athletes are encouraged to alternate between different types of nuts, seeds, and dried fruits that are low in added sugars and added fats
19. Based on Ripple pea-based milk (vanilla)
20. Based on Snow Monkey dairy-free anytime desserts
21. Sunflower seeds, pumpkin seeds, oats, dates, goji berries, hemp seeds
22. The RDA for iron is 1.8 times higher for vegans and vegetarians than for omnivores
23. The RDA for zinc is 1.5 times higher for vegans and vegetarians than for omnivores
24. Plant-based bacon, soymilk, and fortified vanilla plant milk
25. Based on JUST egg, plant-based scramble
26. Contains 7.5 grams of polyunsaturated fatty acids
27. Based on MorningStar Farms veggie bacon strips
28. Contains 5 grams of polyunsaturated fatty acids
29. Also requires vinegar, Dijon mustard, fresh lemon juice, maple syrup, garlic, and salt and pepper
30. Based on Bold Organics vegan cheese pizza
31. Based on Ripple pea-based milk (vanilla)
32. Based on Beyond Meat beyond burger plant-based patties
33. Requires lemon juice, garlic, salt
34. Stir protein powder into yogurt, then top with berries, seeds, and crushed almonds
35. Based on COYO probiotic coconut milk yogurt, available in US, UK, and Australia

Three-day Meal Plan for Adult Female Vegan Olympic-level Endurance Athlete (59kg) by Dotsie Bausch and Tiffany Bruno

Nutritional Content (across 3 days) for nutrients of concern: 364 g protein, 104.5 mg iron (non-heme), 4672 mg calcium, 7.8 g ALA, 41.2 mg zinc, 11 µg vitamin B12.

Endurance athletes demand an intense amount of fuel to power through long, arduous training sessions. This plan provides calorie brackets for three different days of training load for a female endurance athlete at 59kg for a heavy training day, a moderate training day, and an active recovery day. Since there is a lot more to consider beyond calories to optimize performance, each day also exceeds the recommendations for protein, iron, calcium, alpha-linolenic acid, and zinc. This simple menu shows how easy it is to meet an athlete's needs on a plant-based diet, without sacrificing nutrition or flavor. In addition, this very plan was the menu for an actual female Olympic medalist in the sport of track cycling, as she ate a whole-food, plant-based diet exclusively for 24 months leading into her Olympic medal performance.

Sample Menu Day 1: Adult Female, Heavy Training Day (3200 calories)

Menu Item[1]	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)[2]	Zinc (mg)
Nutritional Goal	1.6 g/kg = 94 g	RDA = 32 mg[3]	RDA = 1,000 mg	AI = 1.1 g	RDA = 12 mg[4]
Actual Meal Plan Content with 5.5 µg vitamin B12 from fortified foods[5]	130.8	36.46	2,094.4	1.52	12.6
BREAKFAST					
AB+J TOAST WITH MILK					
2 slices multigrain bread	8	2	75	0.5	1.3
2 tbsp strawberry jam	-	-	-	-	-
2 tbsp almond butter	7	1.1	111	-	1
1 cup fortified vanilla plant milk (Ripple)	8	-	440	-	-

Menu Item[1]	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)[2]	Zinc (mg)
HEAVY TRAINING					
MID TRAINING SNACK					
4 Medjool dates	1.7	0.8	61	-	0.4
2 navel oranges	3	0.9	120	-	0.3
POST TRAINING SNACK					
STRAWBERRY BANANA SMOOTHIE					
1 serving plant-based protein powder (Orgain)	21	6.4	-	-	-
1 scoop creatine monohydrate powder (3 g)	-	-	-	-	-
1 banana	1	0.25	5	-	0.15
1 cup strawberries	1	1.7	35	-	0.3
1 tbsp pumpkin seeds	3	0.8	5	-	0.6
1/2 cup ice	-	-	-	-	-

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)	Zinc (mg)
LUNCH					
MEDITERRANEAN GOODBOWL (click here for recipe)					
1 cup cooked jasmine rice	4	1.9	16	-	0.8
3/4 cup roasted chickpeas	11	3	75	-	1.9
2 cups wild or baby arugula	3	1.5	160	-	0.5
1 tomato (chopped)	1	0.4	12	-	0.2
½ cup sliced cucumber	0.5	0.28	16	-	0.2
⅓ cup sliced pre-cooked beets	0.5	1	9	-	0.1
2 tbsp black or greek olives, pitted	-	0.4	-	-	-
1 oz crumbled non-dairy feta cheese	-	-	-	-	-
2 tbsp store-bought hummus or baba ganoush	3	2.1	9.4	-	-
2 tbsp pine nuts	2	0.8	2	-	0.9
½ cup unsweetened plain non-dairy yogurt	5	1	173	-	-
½ large English cucumber chopped	0.5	0.28	16	-	0.2

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)	Zinc (mg)
AFTERNOON SNACK					
TRAIL MIX					
2 tbsp sunflower kernels	3	0.8	12	-	1
2 tbsp cashews	3	0.9	5	-	0.8
1 tbsp dark chocolate chips	1	1	10	-	-
1/2 cup apple chips	-	-	-	-	-
DINNER					
NOODLE GOODBOWL (click here for recipe)					
1/2 cup kabocha squash	1	0	24	-	0.2
1 brick Pad Thai or ramen noodles (2 oz)	4	0.5	-	-	0.5
1.5 cups frozen Asian or stir-fry vegetables	4	1.2	60	-	-
½ block firm tofu	19	3	254	-	-
1 tsp sesame seeds	0.6	0.2	-	-	0.2
1 cup bok choy leaves	1	0.6	74	-	-
Store-bought Miso Salad Dressing	-	-	-	-	-
EVENING SNACK					
1 banana	1	0.25	5	-	0.15
1/2 oz walnuts	2	0.4	10	0.9	0.4
1 cup soymilk	7	1	300	0.12	0.5

Sample Menu Day 2: Adult Female, Moderate Training Day (2800 calories)

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)	Zinc (mg)
Nutritional Goal	1.6 g/kg = 94 g	RDA = 32 mg	RDA = 1,000 mg	AI = 1.1 g	RDA = 12 mg
Actual Meal Plan Content with 3.0 µg vitamin B12 from fortified foods[5]	113.5	34.55	1320.4	1.66	16.5
BREAKFAST					
SWEET POTATO BREAKFAST BOWL (click here for recipe)					
1 medium-sized baked sweet potato	2	1	39	0.2	0.3
6 oz soy yogurt	6	1	300	-	-
1 cup blueberries	1	0.5	9	-	0.3
2 tbsp finely shredded coconut	1	0	10	-	-
1 tbsp hemp seeds	2	0.8	7	1	1
1 tsp chia seeds	0.5	0.2	8	-	0.2
Ground cinnamon, ground cardamom, salt to taste	-	-	-	-	-
MODERATE TRAINING					
POST TRAINING SNACK					
BANANA BREAD PROTEIN SHAKE					
1 serving plant-based protein powder (Orgain)	21	6.4	-	-	-
1 banana	1	0.25	5	-	0.1
1 tbsp peanut butter	3.5	0.2	7.8	-	0.4
1 cup soymilk	7	1	300	0.12	0.5
1/3 cup oatmeal, uncooked	3	1.2	18.6	-	1.1
1 scoop creatine powder (3 g)	-	-	-	-	-
1/2 cup ice, dash of cinnamon	-	-	-	-	-

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)[2]	Zinc (mg)
LUNCH					
ANTI-INFLAMMATORY LENTIL SOUP*					
2 cans lentils (3 cups)	12	3.5	105	-	1.725
1 can white beans (1.5 cups)	6	1.8	65	-	1.575
1 cup onion, chopped	0.5	-	9	-	0.1
1 cup celery, chopped	-	-	10	-	-
1 cup carrots, chopped	-	0.1	11	-	0.1
4 cloves garlic, 1 tsp turmeric, 1 tsp cumin, 1 tsp thyme, 1/2 tsp black pepper	-	-	-	-	-
8 cups vegetable broth	1	0.4	14	0	0.1
4 cups kale	1	0.3	53	-	0.1
4 cups spinach	1	0.7	25	0.1	0.1
1 lemon, sliced	-	-	-	-	-
1 thick slice sourdough bread	4	1.4	8	-	-

*Nutrition shown per serving. Add lentils through kale to a large pot and simmer on stove for 30 minutes until vegetables are tender. Stir in spinach during last 5 minutes. Serve with bread and lemon slices. Makes 4 servings.

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)	Zinc (mg)
AFTERNOON SNACK					
NACHOS					
½ cup cooked black beans	8	2	60	0.1	3
½ cup salsa or pico de gallo	-	0.5	44	-	-
1 oz multigrain baked tortilla chips	3	0.4	45	-	0.3
DINNER					
LATIN GOODBOWL (click here for recipe)					
2 tbsp roasted pepitas	5	1.6	10	-	1.2
2 tbsp cashew-based sour cream	0	-	5	-	-
1 oz plantain chips	1	0.2	0	-	-
1/2 cup cooked quinoa	4	0.5	16	-	1
1/2 cup cooked lentils	9	3.3	19	0.04	1.3
1 cup cauliflower rice taco filling	2	0.5	24		0.3
½ avocado	2	0.5	12	0.1	0.6
1 cup cherry tomatoes, chopped	1	1.8	50	-	0.3
1 cup romaine lettuce, chopped, reserved	1	0.5	16	-	0.1
Garnishes: red onion, bell peppers, salsa	-	-	-	-	-

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)	Zinc (mg)
EVENING SNACK					
COOKIE DOUGH RICE CAKES					
2 salted rice cakes	1	0.2	-	-	-
1 tbsp cashew butter	2	0.8	10	-	0.7
1 tbsp semi-sweet chocolate chips	1	1	5	-	-


Latin Goodbowl

Sample Menu Day 3: Adult Female, Active Recovery Day (2200 calories)

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)	Zinc (mg)
Nutritional Goal	1.6 g/kg = 94 g	RDA = 32 mg	RDA = 1,000 mg	AI = 1.1 g	RDA = 12 mg
Actual Meal Plan Content with 2.5 μg vitamin B12 from fortified foods[5]	119.6	33.45	1257	4.64	12.05
BREAKFAST					
GREEN BERRY SMOOTHIE					
1 banana	1	0.25	5	-	0.15
1 cup blackberries	2	1	40	-	0.8
1 tbsp hemp seeds	2	0.8	7	1	1
1 tbsp chia seeds	1.6	0.5	23	-	0.5
1 cup kale	1	0.3	53	-	0.1
1/2 cup ice	-	-	-	-	-
MORNING SNACK					
OVERNIGHT OATS					
1 cup fortified vanilla plant milk (Ripple)	8	-	440	-	-
1/2 cup rolled oats	6	2	12	0.1	1.8
2 tbsp ground flaxseed	2.6	0.8	35	3.2	0.6
1 tbsp pumpkin seeds	3	0.8	5	-	0.6
1.5 oz raisins	1.4	0.7	27	-	0.1

Menu Item	Protein (g)	Iron (mg)	Calcium (mg)	ALA (g)	Zinc (mg)
LUNCH					
WESTERN BBQ GOODBOWL (click here for recipe)					
1/2 cup canned vegan baked beans	8	3.5	70	-	-
1 cup roasted white, russet or redskin potatoes, diced	3	0.8	14	-	0.4
100 g smoky tempeh bacon strips	20	2.1	96	-	1.6
1 cup slaw mix	1	0.4	52	-	0.2
1 tbsp vegan mayonnaise	-	-	-	-	-
AFTERNOON SNACK					
½ cup cinnamon-roasted chickpeas	15	4	100	-	2.5
2 tbsp shelled pistachios	3	0.5	15	0.04	0.3
DINNER					
HEARTY PESTO PASTA					
2 oz edamame spaghetti	24	11	110	0.3	-
1/2 cup vegan "meat" crumbles	10	1.2	60	-	-
1/2 cup cherry tomatoes, chopped	1	0.9	25	-	0.2
2 tbsp dairy-free pesto	-	-	-	-	-
Fresh Italian herbs (basil, oregano, etc)	-	-	-	-	-
EVENING SNACK					
1/4 cup hummus	5	1.5	28	-	0.9
1 cup baby carrots	1	0.4	40	-	0.3

NOTES: [1] Nutritional facts sourced from USDA, FoodData Central, 2021 [2] Alpha-linolenic acid [3] The recommended dietary allowance (RDA) for iron is 1.8 times higher for vegans and vegetarians than for omnivores [4] The RDA for zinc is 1.5 times higher for vegans and vegetarians than for omnivores [5] Fortified vanilla plant milk and soymilk

Personalizing Your Program

Personalizing caloric recommendations to fit your own needs is very simple. The nutrient recommendations are determined by the difficulty of your workouts and in particular by the combination of the workout intensity and duration. First, you'll figure out how much and how hard you work out. After evaluating the difficulty of your workout, you'll calculate the exact recommended intakes of carbohydrates and protein necessary for optimal adaptations based upon that training load and your body weight.

After these two nutrient levels are determined, you'll select your fat intake based on 10 to 20 percent of your total calories. If you are interested in weight loss or maintenance or are exercising for relatively short periods of time, you can have adequate energy (calories) with 10 percent fat, combined with appropriate protein and carbohydrate intakes. If you're involved in endurance exercise and particularly if you are working out longer than two hours a day, up the percentage toward the 20 percent limit. The tables and calculators below will assist you in determining your personal intake levels.

Post-exercise Nutrient Intake

The first two hours after exercise (window of opportunity) are critical for muscle glycogen resynthesis and recovery. You need a combination of carbohydrate & protein aids:

- Glycogen resynthesis and compensation are enhanced
- Improves endocrine and nutrient environment for adaptation
- Limits catabolic breakdown and enhances anabolic repair

Guidelines

- 1:4 to 1:3 protein/carbohydrate ratio, depending on bodyweight
- 15-25 g protein plus 50-75 g carbohydrate immediately after exercise and repeat after an hour (or eat a meal)
- Sports recovery drinks (meal replacement shakes) boost energy and fluid replacement over solid foods

Protein and Performance

Protein requirements for athletes are greater than sedentary population's recommended daily intake (RDI) of 0.8 g per kilogram of body weight: the recommended range is 1-2 g per kilogram of bodyweight per day. Higher amounts are not beneficial and can be detrimental.

Re-establishing plasma amino acids after exercise is critical for the shift from the catabolic state to the anabolic state necessary for recovery and adaptation.

Bodyweight (lb)	Low Intensity g/day (kcal)	Moderate Intensity g/day (kcal)	High Intensity g/day (kcal)
100	46 (184)	69 (276)	92 (368)
110	50 (200)	75 (300)	100 (400)
120	55 (220)	83 (332)	110 (440)
130	59 (236)	89 (355)	118 (472)
140	64 (256)	95 (380)	128 (512)
150	68 (273)	102 (408)	136 (544)
160	73 (292)	110 (440)	146 (584)
170	77 (309)	116 (464)	154 (616)
180	82 (328)	123 (492)	164 (656)
190	86 (345)	129 (516)	172 (688)
200	91 (364)	137 (548)	182 (728)

Bodyweight (lb)	Low Intensity g/day (kcal)	Moderate Intensity g/day (kcal)	High Intensity g/day (kcal)
210	95 (382)	143 (572)	190 (760)
220	100 (400)	150 (600)	200 (800)
230	105 (420)	158 (632)	210 (840)
240	109 (436)	164 (656)	218 (872)
250	114 (456)	171 (684)	228 (912)
260	118 (472)	177 (708)	236 (944)
270	123 (492)	185 (740)	246 (984)
280	127 (508)	191 (764)	254 (1016)
290	132 (528)	198 (792)	264 (1056)
300	136 (544)	204 (816)	272 (1088)

If your bodyweight is not listed above, use following equations to determine your individual daily protein requirement:

Low Intensity:
[(Body weight) / (2.2 kg/lb)] x (1.0 g/kg/day) = ________ g/day x 4 Cal/g = ________ Calories

Moderate Intensity:
[(Body weight) / (2.2 kg/lb)] x (1.5 g/kg/day) = ________ g/day x 4 Cal/g = ________ Calories

High Intensity:
[(Body weight) / (2.2 kg/lb)] x (2.0 g/kg/day) = ________ g/day x 4 Cal/g = ________ Calories

Daily protein recommendations based on training intensity levels and bodyweight are as follows:
Low Intensity - 1.0 g/kg/day
Moderate Intensity - 1.5 g/kg/day
High Intensity - 2.0 g/kg/day

Bodyweight (lb)	Low Intensity g/day (kcal)	Moderate Intensity g/day (kcal)	High Intensity g/day (kcal)
100	318 (1272)	386 (1544)	455 (1820)
110	350 (1400)	425 (1700)	500 (2000)
120	382 (1528)	464 (1856)	545 (2180)
130	414 (1656)	503 (2012)	590 (2360)
140	445 (1780)	541 (2164)	636 (2544)
150	476 (1904)	578 (2312)	680 (2720)
160	509 (2036)	618 (2472)	727 (2908)
170	539 (2156)	655 (2620)	770 (2908)
180	574 (2296)	697 (2788)	820 (3280)
190	602 (2408)	731 (2924)	860 (3440)
200	636 (2544)	773 (3092)	909 (3636)

Bodyweight (lb)	Low Intensity g/day (kcal)	Moderate Intensity g/day (kcal)	High Intensity g/day (kcal)
210	665 (2660)	808 (3232)	950 (3800)
220	700 (2800)	850 (3400)	1000 (4000)
230	735 (2940)	893 (3572)	1050 (4200)
240	764 (3056)	927 (3708)	1091 (4364)
250	798 (3192)	969 (3976)	1140 (4560)
260	827 (3308)	1005 (4020)	1182 (4728)
270	861 (3444)	1046 (4184)	1230 (4920)
280	891 (3564)	1082 (4328)	1273 (5092)
290	924 (3696)	1122 (4488)	1320 (5280)
300	955 (3820)	1159 (4636)	1364 (5456)

If your bodyweight is not listed above, use following equations to determine your individual daily carbohydrate requirement:

Low Intensity:
[(Body weight) / (2.2 kg/lb)] x (7.0 g/kg/day) = ________ g/day x 4 Cal/g = ________ Calories

Moderate Intensity:
[(Body weight) / (2.2 kg/lb)] x (8.5 g/kg/day) = ________ g/day x 4 Cal/g = ________ Calories

High Intensity:
[(Body weight) / (2.2 kg/lb)] x (10.0 g/kg/day) = ________ g/day x 4 Cal/g = ________ Calories

Daily carbohydrate recommendations based on training intensity levels and bodyweight are as follows:
Low Intensity - 7.0 g/kg/day
Moderate Intensity - 8.5 g/kg/day
High Intensity - 10.0 g/kg/day

A diet that is optimal for health and disease prevention is also optimal for athletic performance, particularly in terms of lipid intake:

- 10-20% of total calories should be lipid (depending on the athlete)
- Low saturated fatty acid (SFA) and/or trans fats: <3% of total kilocalories
- SFAs impede oxygen transport, delivery, and VO2 max
- High n-3/n-6 ratio (from lipid metabolism) reduces systemic inflammation and improves membrane properties and hormone/receptor responsiveness

If your bodyweight is not listed below, use following equations to determine your individual daily requirement:

@10% of total calories from fat:
[(g protein) + (g carbohydrates)] x (0.049) = _____ g/day x 9 Cal/g = _____ Calories

@20% of total calories from fat:
[(g protein) + (g carbohydrates)] x (0.0112) = _____ g/day x 9 Cal/g = _____ Calories

Bodyweight (lb)	Low Intensity @10% / @20% g fat/day (kcal)	Moderate Intensity @10% / @20% g fat/day (kcal)	High Intensity @10% / @20% g fat/day (kcal)
100	18 (162) / 41 (369)	22 (198) / 51 (459)	27(243) / 61 (549)
110	20 (180) / 45 (405)	25 (225) / 56 (504)	29 (261) / 67 (603)
120	21 (189) / 49 (441)	27 (243) / 61 (549)	32 (288) / 73 (657)
130	23 (207) / 53 (477)	29 (261) / 66 (594)	35 (315) / 79 (711)
140	25 (225) / 57 (513)	31 (279) / 71 (639)	38 (342) / 85 (765)
150	27 (243) / 61 (549)	33 (297) / 76 (684)	40 (360) / 91 (819)
160	29 (261) / 65 (585)	35 (315) / 81 (729)	43 (387) / 97 (873)
170	30 (270) / 69 (621)	38 (342) / 86 (774)	45 (405) / 103 (927)
180	32 (288) / 73 (657)	40 (360) / 91 (819)	48 (432) / 109 (981)
190	34 (306) / 77 (693)	42 (378) / 96 (864)	51 (459) / 115 (1035)
200	36 (324) / 81 (729)	45 (405) / 102 (918)	53 (477) / 121 (1089)

Bodyweight (lb)	Low Intensity @10% / @20% g fat/day (kcal)	Moderate Intensity @10% / @20% g fat/day (kcal)	High Intensity @10% / @20% g fat/day (kcal)
210	38 (342) / 85 (765)	47 (423) / 106 (954)	56 (504) / 127 (1143)
220	39 (351) / 90 (810)	49 (441) / 112 (1008)	59 (531) / 134 (1206)
230	41 (369) / 94 (846)	51 (459) / 118 (1062)	62 (558) / 141 (1269)
240	43 (387) / 98 (882)	53 (477) / 122 (1198)	64 (576) / 147 (1323)
250	45 (405) / 102 (918)	56 (504) / 128 (1152)	67 (603) / 153 (1377)
260	46 (414) / 106 (954)	58 (522) / 132 (1188)	69 (621) / 159 (1431)
270	48 (432) / 110 (989)	60 (540) / 138 (1242)	72 (648) / 165 (1485)
280	50 (450) /114 (1026)	62 (558) / 143 (1287)	75 (675) / 171 (1539)
290	52 (468) / 118 (1062)	65 (585) / 148 (1332)	78 (702) / 177 (1593)
300	53 (477) / 122 (1198)	67 (603) / 153 (1377)	80 (720) / 183 (1647)

What to Expect

Tracking Performance

When it comes down to it, adopting a plant-based diet is all about results. How can an athlete tell if a plant-based diet is working for them? Besides a blood draw (which is recommended to see long-term results for overall health), here are several ways for athletes to check in with themselves and qualitatively measure the impact a plant-based diet is having on their performance.

Gut

- Less bloat, stomach pain, cramping, constipation, and gas
- More regular bowel movements

Lungs

- Less mucus during or after exercise (less spitting and runny nose)
- Ability to breathe better during exercise
- Less severe allergy symptoms

Energy Levels and Recovery

- Less time needed to “get in the groove” during warm-ups
- Feeling more energized
- Less tired/fatigued
- Less grogginess in the morning
- Faster recovery time

Mood

- Clearer mind
- Higher concentration
- Generally better feeling of well-being

Soreness and Stiffness

- Less soreness—severity or duration
- Less inflammation
- Less joint stiffness

David Verburg, Plant-based Athlete
Olympic Gold, 2016

Plant-based Athlete Profile
Cheavon Clarke, Team GB Boxing

Event: Heavyweight Boxing
Plant-based since: 2018
Signature dish: Vegan Jamaican Hotpot

2019 European Games (Bronze)
2018 EU Championships (Bronze)
2018 Commonwealth Games (Bronze)
2017 European Championships (Silver)

Why did you switch to a plant-based diet?

Being Jamaican, I’ve always enjoyed delicious, flavorful food. As an adult, I always tried to eat healthy—especially when I became a serious athlete. But I started noticing, I would eat something and just feel like something wasn’t right. I realized it was always after I’d eaten dairy or meat. Then, I watched *The Game Changers*—and the lightbulb went on.

How did the switch improve your performance?

My strength, energy, and endurance are all crazy good. I’ve experienced three big improvements—recovery, digestion, and overall health. When I ate meat and dairy, it would be an hour or two before I could go back in the ring. On my vegan diet, I’m ready to go in 30 minutes. Even my complexion and concentration are better.

What’s your favorite plant-based food?

Not to brag, but I’m a pretty good cook. My Jamaican mum had me cooking as a kid. I did all the cooking for the guys at the Olympic training camp in Sheffield. I basically use tofu and other plant-based ingredients to make vegan versions of all my favourite meals. My signature dish is my Vegan Jamaican Hotpot. I use a lot of Jamaican spices in my cooking. Anybody who tells you vegan food is bland and tasteless hasn’t been to my house.

What would you tell an athlete who’s on the fence?

Just try it! I don’t lecture anybody. I believe it’s a healthier way to eat. I’ve never felt better in my life. I still hear people say things like: “You need proper animal proteins to be fit and strong—to perform as an athlete.” I say: “Why don’t you come and do three rounds in the ring with me.” Athletes are strong-willed and very self-motivated people. But if another boxer asked me whether they should switch to a plant-based diet, I would simply say: “Try it. Drop dairy and you’ll probably feel better immediately. When you’re ready, go full-on plant-based and see for yourself."

"It was like rocket fuel."

Plant-based Athlete Profile
Dotsie Bausch, Team USA Cycling

Event: Track Cycling
Plant-based since: 2009
Signature dish: "Trough" Bowl with Tahini

2012 London Olympics (Silver)
2010 World Record Holder
2010 & 2007 Pan-American Champion

Who is Dotsie Bausch?

I am an American cyclist and the oldest athlete to earn an Olympic medal in my discipline—male or female—at 39 years old. I credit my longevity in professional cycling to my plant-based diet. I ditched all animal foods—meat, fish, eggs, and dairy—two and a half years prior to the 2012 Olympic Games and experienced a physical boost in my performance and recovery within weeks. It was like rocket fuel!

Why did you switch to a dairy-free, plant-based diet?

I originally adopted a plant-based diet for reasons beyond performance. I no longer wished to contribute to a corrupt system of normalized abuse and violence against animals. Coaches told me this moral decision might jeopardize my chances of making the US Olympic team, but to everyone's surprise, it made me stronger. I greatly improved my strength, maxing out at pressing 585 lb of 60 reps for six sets compared to 300 lb of 30 reps for five before switching to a plant-based diet. I just felt more energized during training sessions and could more than keep pace with my teammates—some 10 years my junior. Moreover, my recovery time drastically decreased. I felt fresher, quicker, and needed far less time to recover in between workouts. When training day in and day out, this quick recovery element was critical to my success.

Dotsie's bottom line

Olympic dreams don't have to be limited to your teens and early twenties. Professional athletes who love what they do can continue to compete at an Olympic level if they fuel their bodies right. A plant-based diet did that for me, and I believe any athlete who values longevity in sport should adopt a plant-based diet as well.

How to Learn More

These additional programs will support your athletes in pursuit of optimum, plant-strong nutrition and athletic excellence. Start with the Lactose Intolerance Test. Learn more about specific nutrition and performance topics with a live webinar or cooking demo. Get meaningful results with the Plant-based Performance Challenge. All of these are here for you and your team to perform at its very best.

Lactose Intolerance Screening

Over 68% of the global population is lactose intolerant, but many are undiagnosed. This quick test is the first online tool to pinpoint lactose intolerance. These six multiple choice questions can help anyone determine whether they are lactose intolerant, lactose sensitive, or lactose persistent.

Take the test: switch4good.org/lactose-intolerance-test

Live Educational Webinar with Plant-strong Experts

Engage and learn from plant-strong physicians, dietitians, and professional athletes during our customized webinars. Each virtual session will be tailored to your interests, allowing you to learn more about the plant-strong diet and how it affects performance. Our experts have decades of experience in the plant-based nutrition and our physicians and dietitians use an evidence-based approach. Sometimes, new information is more digestible when given within a conversation instead of a book.

Schedule your plant-strong webinar: plantbasedplaybook@switch4good.org

Virtual Interactive Cooking Demo

Knowing how to cook for oneself is an invaluable tool—particularly for athletes. Our live virtual cooking demonstrations will empower athletes to cook nutrient-dense, plant-strong meals quickly and efficiently. Taught by cookbook author and Cooking Channel host Jason Wrobel, these demonstrations can be tailored to any culinary skill level.

Schedule your cooking demonstration: plantbasedplaybook@switch4good.org

12-week Plant-based Performance Challenge

This comprehensive plan will provide a quantitative analysis of the effects of a plant-based diet on your athletes' performance. Athletes will commit to a plant-strong diet for a 12-week period and results will be measured via biomarkers (taken from weekly blood draws), performance benchmarks, and a pre- and post-qualitative athlete survey. The evidence will show just how effective a plant-based diet can be within just a short period of time.

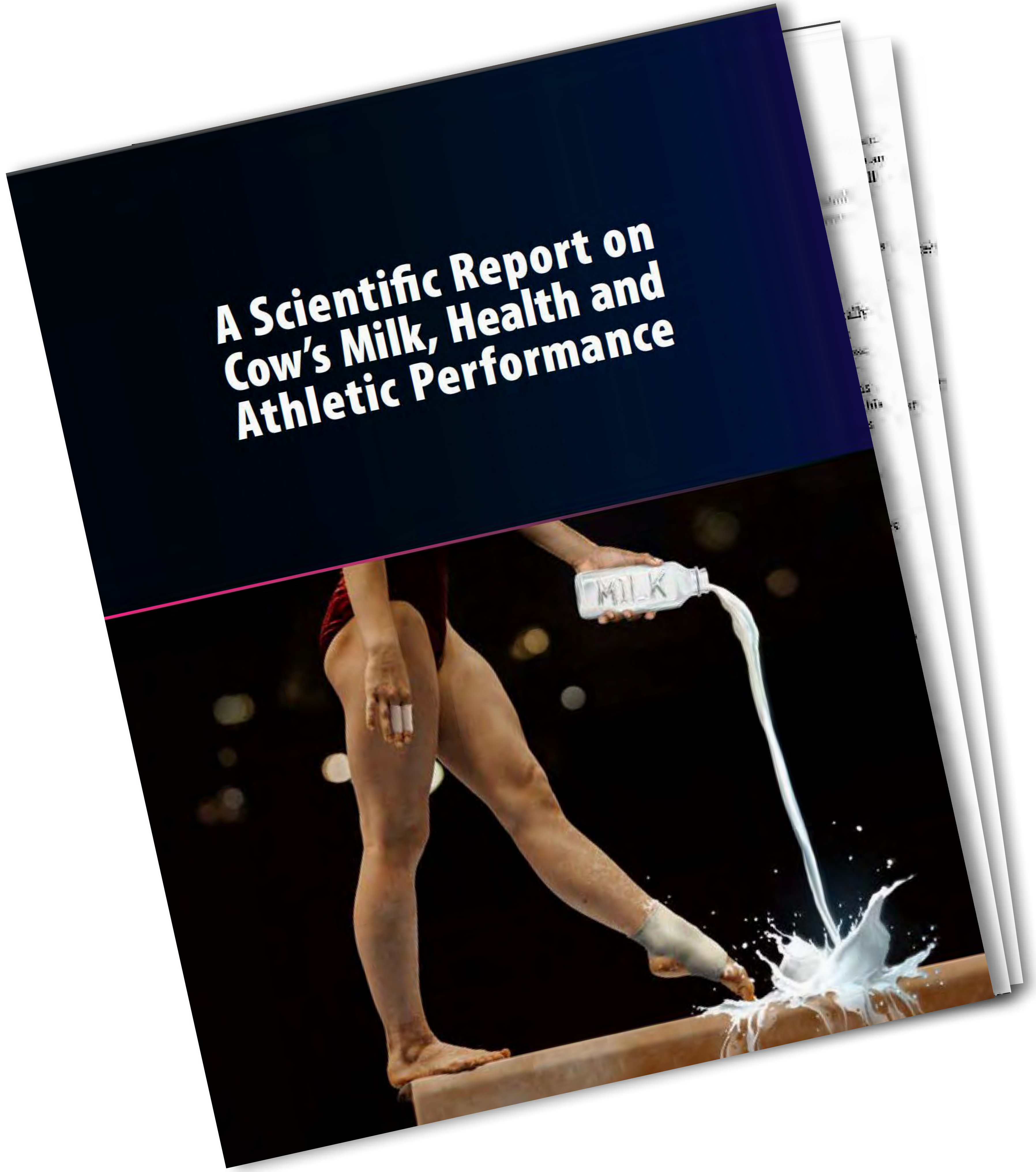
Schedule a consultation: plantbasedplaybook@switch4good.org

A Scientific Report on Cow's Milk, Health, and Athletic Performance

For over a century, cow's milk has been touted as a healthy part of a balanced diet. Celebrity athletes pose sporting milk mustaches. Chocolate milk is promoted as an exercise recovery beverage. And the idea that milk builds strong bones and muscles is best exemplified by the advertising campaign; "Milk does a body good." All very effective marketing, but is it good science?

Based on rigorously cited essays by physicians, dietitians, and other health and nutrition experts, this report challenges the conventional wisdom that cow's milk is healthy for humans. It seeks to educate and empower all of us—athletes included—to take back control of our nutrition, exceed our performance goals, and maximize our capacity for a long, healthy life.

Athletes are always striving to improve. But physical training is limited without the proper fuel. Dozens of professional and Olympic athletes—from Lionel Messi to Alex Morgan—have leveled up their performance and extended the longevity of their careers by changing their diet. Eliminating dairy was the common denominator.



To download a copy of this comprehensive, evidence-based report, click here: https://switch4good.org/scientific-report

GLOSSARY

Angiogenesis - the normal process of growing new (genesis) blood vessels (angio) that is controlled by a precise balance of start and stop, or pro-angiogenic and anti-angiogenic signals

Anthocyanins - compounds naturally produced in some fruits and vegetables that contribute to purple, blue, and red pigmentation

Atherosclerosis - buildup of fat and cholesterol in the artery walls

Carotenoids - compounds naturally produced in some fruits and vegetables that contribute to yellow and orange pigmentation, with immune-enhancing properties

Chondrocytes - cells that produce and maintain healthy cartilage

Conditionally Essential Amino Acid - non-essential amino acids that can become essential and need to be consumed through diet under certain circumstances such as illness

Endothelium - single layer of cells that line blood vessels

Ergogenic Aids – any substance (nutritional, pharmacologic, physiologic, or psychologic) claiming to directly or indirectly enhance performance, energy, and/or recovery. Common examples include creatine, carnosine, beta-alanine, and caffeine.

Erythropoiesis - production of red blood cells, which supply oxygen to all organs and tissues in the body. This process is enabled by iron.

Flavonoids - compounds naturally produced in plants and may provide health benefits

Glucosinolates - pungent compounds naturally produced in plants such as mustard, with immune-enhancing properties

Ileal Digestibility - difference between amino acids ingested and recovered from digesta in the ileum

Inflammatory Cytokines - proteins used to communicate between immune system cells and recruit other inflammatory white cells

Metabolic Syndrome - a cluster of conditions that set the stage for diabetes and heart disease such as high blood pressure, high blood sugar, excess body fat around the waist, and abnormal cholesterol levels

Metabolite - substance produced during metabolism as an intermediate or final product

Myelinating Cells – important in nerve regeneration and transmitting electrical impulses along the axons

Myofibril - contracting units of muscle cells

Myogenesis – creation of muscle fibers and tissue

Phytates - antioxidant compounds found in some plants that can bind to certain nutrients and inhibit absorption

Phytochemicals - active substances found in plants that may provide unique health benefits to the human body

Phytoestrogen - a type of plant estrogen that is similar in function to human estrogen but with much weaker effects and known to improve vascular function and blood flow

GLOSSARY

Polyphenols - plant compounds rich in antioxidants found in colorful vegetables and fruits that provide health benefits

Reactive Oxygen Species - highly reactive compounds in the body that can cause damage to cells, reduce energy production, and drive inflammation

Short Chain Fatty Acids (SCFAs) - by-products of fiber digestion that act as endogenous signals to guide important physiological roles

Supratherapeutic Doses - dose greater than the typical medical dose

Vasodilator - substance that opens (dilates) blood vessels and allows blood to flow more easily, reducing blood pressure

AI – adequate intake

ALA – alpha-linolenic acid

ASF – animal-sourced food

BCAA – branched-chain amino acid

CHO – carbohydrate

CSA – cross-sectional area

DHA – docosahexaenoic acid

DIAAS – digestible indispensable amino acid score

EAA – essential amino acid

EB – energy balance

EGCG – epigallocatechin-3-gallate

EPA – eicosapentaenoic acid

ER – energy restriction

FAO – Food and Agriculture Organization of the United Nations

FDA – Food and Drug Administration

IBS – irritable bowel syndrome

IOC – International Olympic Committee

IU – international units

LPS – lipopolysaccharide

MPB – muscle protein breakdown

MPS – muscle protein synthesis

NCD – non-communicable disease

NPB – net protein balance

PB – plant-based

PUFA – polyunsaturated fatty acids

RBC – red blood cell

RDA – recommended dietary allowance

RET – resistance exercise training

ROS – reactive oxygen species

SCFA – short chain fatty acid

SIBO – small intestinal bacterial overgrowth

UIC – urinary iodine concentrations

UNU – United Nations University

WHO – World Health Organization

REFERENCES

Section 1: The Power of a Plant-based Plate to Optimize Biologic Systems

1. Di Sebastiano, Katie M., and Marina Mourtzakis. “The role of dietary fat throughout the prostate cancer trajectory.” Nutrients6.12 (2014): 6095-6109.
2. Machado, Maria JC, et al. “Dynamics of angiogenesis during wound healing: a coupled in vivo and in silico study.” Microcirculation 18.3 (2011): 183-197.
3. Tenaglia AN, Peters KG, Sketch MHJr, Annex BH. Neovascularization in atherectomy specimens from patients with unstable angina: implications for pathogenesis of unstable angina. Am Heart J 1998;135(1):10–14.
4. Plaza, Adrián, et al. “Inflammatory stress and altered angiogenesis evoked by very high-fat diets in mouse liver.” Endocrinologia, diabetes y nutricion 66.7 (2019): 434-442.
5. Stewart, Kelly L., et al. “Association of Sugar Intake with Inflammation-and Angiogenesis-Related Biomarkers in Newly Diagnosed Colorectal Cancer Patients.” Nutrition and Cancer(2021): 1-8.
6. Emerson, Sam R., et al. “High-fat meal–induced changes in markers of inflammation and angiogenesis in healthy adults who differ by age and physical activity level.” Current developments in nutrition 3.1 (2019): nzy098.
7. Ardakanizade, M. The effects of mid- and long-term endurance exercise on heart angiogenesis and oxidative stress. Iran. J. Basic Med. Sci. 2018, 21, 800–805.
8. Ardakanizade, Malihe. “The effects of mid-and long-term endurance exercise on heart angiogenesis and oxidative stress.” Iranian journal of basic medical sciences 21.8 (2018): 800.
9. Balberova, Olga V., et al. “The “Angiogenic Switch” and Functional Resources in Cyclic Sports Athletes.” International Journal of Molecular Sciences 22.12 (2021): 6496.
10. Arsic, N.; Zacchigna, S.; Zentilin, L.; Ramirez-Correa, G.; Pattarini, L.; Salvi, A.; Sinagra, G.; Giacca, M. Vascular endothelial growth factor stimulates skeletal muscle regeneration in Vivo. Mol. Ther. 2004, 5, 844–854.
11. Angiogenesis-based medicine: principles and practice for disease prevention and intervention, in: Angiogenesis: Basic Science and Clinical Applications, Research Signpost, 2008.
12. Fan, Tai-Ping, et al. “Angiogenesis: from plants to blood vessels.” Trends in Pharmacological Sciences 27.6 (2006): 297-309.
13. Munir, Samman, et al. “Anti-angiogenesis potential of phytochemicals for the therapeutic management of tumors.” Current pharmaceutical design 26.2 (2020): 265-278.
14. Sarkar, Priyanka, and Kavitha Thirumurugan. “Modulatory functions of bioactive fruits, vegetables and spices in adipogenesis and angiogenesis.” Journal of Functional Foods53 (2019): 318-336.
15. Tsakiroglou, Panagiotis, et al. “Role of berry anthocyanins and phenolic acids on cell migration and angiogenesis: an updated overview.” Nutrients 11.5 (2019): 1075.
16. Pieczenik, Steve R., and John Neustadt. “Mitochondrial dysfunction and molecular pathways of disease.” Experimental and molecular pathology 83.1 (2007): 84-92.
17. Mitochondrial dynamics in the regulation of nutrient utilization and energy expenditure. Liesa M, Shirihai OS Cell Metab. 2013 Apr 2; 17(4):491-506.
18. Yang, Chenjing, et al. “Mitochondrial dysfunction in insulin resistance: differential contributions of chronic insulin and saturated fatty acid exposure in muscle cells.” Bioscience reports 32.5 (2012): 465-478.
19. Hirabara, Sandro M., Rui Curi, and Pierre Maechler. “Saturated fatty acid-induced insulin resistance is associated with mitochondrial dysfunction in skeletal muscle cells.” Journal of cellular physiology 222.1 (2010): 187-194.
20. Apaijai, Nattayaporn, et al. “High-saturated fat high-sugar diet accelerates left-ventricular dysfunction faster than high-saturated fat diet alone via increasing oxidative stress and apoptosis in obese-insulin resistant rats.” Molecular nutrition & food research 63.2 (2019):
21. Saint-Georges-Chaumet, Yann, and Marvin Edeas. “Microbiota–mitochondria inter-talk: consequence for microbiota–host interaction.” Pathogens and disease 74.1 (2016).
22. Dahl, Wendy J., and Maria L. Stewart. “Position of the Academy of Nutrition and Dietetics: health implications of dietary fiber.” Journal of the Academy of Nutrition and Dietetics 115.11 (2015): 1861-1870.
23. Rose S Bennuri SC Davis JE Wynne R Slattery JC Tippett M , et al. Butyrate enhances mitochondrial function during oxidative stress in cell lines from boys with autism. Transl Psychiatry 2018; 8: 42.
24. Silva, Vagner R., et al. “β-Hydroxy-β-methylbutyrate free acid supplementation may improve recovery and muscle adaptations after resistance training: A systematic review.” Nutrition research 45 (2017): 1-9.
25. He, Xi, et al. “β-Hydroxy-β-methylbutyrate, mitochondrial biogenesis, and skeletal muscle health.” Amino acids 48.3 (2016): 653-664.
26. Ferrara, Luigi, Marko Joksimovic, and Stefania D’Angelo. “Modulation of mitochondrial biogenesis: Action of physical activity and phytochemicals.” Journal of Physical Education and Sport 21.1 (2021): 425-433.
27. Naoi, Makoto, et al. “Mitochondria in neuroprotection by phytochemicals: Bioactive polyphenols modulate mitochondrial apoptosis system, function and structure.” International journal of molecular sciences 20.10 (2019): 2451.
28. 9. Powers SK, Radak Z, Ji LL. Exercise-induced oxidative stress: past, present and future. J. Physiol. 2016; 594:5081–92.
29. Bouchez C, Devin A. Mitochondrial biogenesis and mitochondrial reactive oxygen species (ROS): a complex relationship regulated by the cAMP/PKA Signaling pathway. Cell. 2019; 8.
30. Massaro M, Scoditti E, Carluccio MA, et al. Effect of cocoa products and its polyphenolic constituents on exercise performance and exercise-induced muscle damage and inflammation: a review of clinical trials. Nutrients. 2019; 11.
31. Hamidie, R. D. R., and K. Masuda. “Curcumin potentially to increase athlete performance through regulated mitochondrial biogenesis.” IOP Conference Series: Materials Science and Engineering. Vol. 180. No. 1. IOP Publishing, 2017.
32. Chodari, Leila, et al. “Targeting Mitochondrial Biogenesis with Polyphenol Compounds.” Oxidative Medicine and Cellular Longevity 2021 (2021).
33. Silva RFM, Pogačnik L. Polyphenols from food and natural products: neuroprotection and safety. Antioxidants (Basel). 2020; 9: pii: E61.
34. Travica, Nikolaj, et al. “The effect of blueberry interventions on cognitive performance and mood: A systematic review of randomized controlled trials.” Brain, behavior, and immunity 85 (2020): 96-105.
35. Bayes, Jessica, Janet Schloss, and David Sibbritt. “Effects of polyphenols in a Mediterranean diet on symptoms of depression: a systematic literature review.” Advances in Nutrition 11.3 (2020): 602-615.

36. D'Angelo, Stefania. "Polyphenols: Potential beneficial effects of these phytochemicals in athletes." Current Sports Medicine Reports 19.7 (2020): 260-265.
37. D'Angelo, Stefania. "Polyphenols: Potential beneficial effects of these phytochemicals in athletes." Current Sports Medicine Reports 19.7 (2020): 260-265.
38. 21.Frampton J, Murphy KG, Frost G, Chambers ES. Short-chain fatty acids as potential regulators of skeletal muscle metabolism and function. Nat Metab. 2020;2(9):1–9.
39. Hawley JA. Microbiota and muscle highway—two way traffic. Nat Rev Endocrinol. 2019;16(2):1–2.
40. Frampton J, Murphy KG, Frost G, Chambers ES. Short-chain fatty acids as potential regulators of skeletal muscle metabolism and function. Nat Metab. 2020;2(9):1–9.
41. Donati Zeppa S, Agostini D, Gervasi M, Annibalini G, Amatori S, Ferrini F, Sisti D, Piccoli G, Barbieri E, Sestili P. Mutual interactions among exercise, sport supplements and microbiota. Nutrients. 2020;12(1):17.
42. Clauss M, Gérard P, Mosca A, Leclerc M. Interplay Between Exercise and Gut Microbiome in the Context of Human Health and Performance. Front Nutr. 2021;8:637010. Published 2021 Jun 10. doi:10.3389/fnut.2021.637010
43. David, Lawrence A., et al. "Diet rapidly and reproducibly alters the human gut microbiome." Nature 505.7484 (2014): 559-563.
44. Ahrens, Angelica P., et al. "A Six-Day, Lifestyle-Based Immersion Program Mitigates Cardiovascular Risk Factors and Induces Shifts in Gut Microbiota, Specifically Lachnospiraceae, Ruminococcaceae, Faecalibacterium prausnitzii: A Pilot Study." Nutrients 13.10 (2021): 3459
45. Devkota, S. et al. Dietary-fat-induced taurocholic acid promotes pathobiont expansion and colitis in Il10−/− mice. Nature 487, 104–108 (2012)
46. Clark, Allison, and Núria Mach. "The crosstalk between the gut microbiota and mitochondria during exercise." Frontiers in physiology 8 (2017): 319.
47. Donati Zeppa S, Agostini D, Gervasi M, Annibalini G, Amatori S, Ferrini F, Sisti D, Piccoli G, Barbieri E, Sestili P. Mutual interactions among exercise, sport supplements and microbiota. Nutrients. 2020;12(1):17.
48. Noble, Emily E., Ted M. Hsu, and Scott E. Kanoski. "Gut to brain dysbiosis: mechanisms linking western diet consumption, the microbiome, and cognitive impairment." Frontiers in behavioral neuroscience 11 (2017): 9.
49. Relationship between gastro-intestinal complaints and endotoxaemia, cytokine release and the acute-phase reaction during and after a long-distance triathlon in highly trained men. Jeukendrup AE, Vet-Joop K, Sturk A, Stegen JH, Senden J, Saris WH, Wagenmakers AJ Clin Sci (Lond). 2000 Jan; 98(1):47-55.
50. Kien CL, Bunn JY, Fukagawa NK, Anathy V, Matthews DE, Crain KI, Ebenstein DB, Tarleton EK, Pratley RE, Poynter ME. Lipidomic evidence that lowering the typical dietary palmitate to oleate ratio in humans decreases the leukocyte production of proinflammatory cytokines and muscle expression of redox-sensitive genes. J Nutr Biochem. 2015 Dec;26(12):1599-606.
51. Pendyala S, Walker JM, Holt PR. A high-fat diet is associated with endotoxemia that originates from the gut. Gastroenterology. 2012 May;142(5):1100-1101.
52. Lopez-Moreno J, Quintana-Navarro GM, Camargo A, Jimenez-Lucena R, Delgado-Lista J, Marin C, Tinahones FJ, Striker GE, Roche HM, Perez-Martinez P, Lopez-Miranda J, Yubero-Serrano EM. Dietary fat quantity and quality modifies advanced glycation end products metabolism in patients with metabolic syndrome. Mol Nutr Food Res. 2017 Aug;61(8).
53. Benson, Sven, et al. "Effects of acute systemic inflammation on the interplay between sad mood and affective cognition." Translational psychiatry 7.12 (2017): 1-10.
54. Saint-Georges-Chaumet, Yann, and Marvin Edeas. "Microbiota–mitochondria inter-talk: consequence for microbiota–host interaction." Pathogens and disease 74.1 (2016).
55. André, Perrine, et al. "Mediterranean diet and prudent diet are both associated with low circulating esterified 3-hydroxy fatty acids, a proxy of LPS burden, among older adults." The American Journal of Clinical Nutrition (2021).
56. Elce, Ausilia, et al. "Anti-inflammatory activity of butyrate: therapeutic effects, educative strategies and potential implications for an athlete's health." Journal of Physical Education and Sport 18.2 (2018): 654-662.
57. Clarke, Siobhan F., et al. "Exercise and associated dietary extremes impact on gut microbial diversity." Gut 63.12 (2014): 1913-1920.
58. Neale EP, Batterham MJ & Tapsell LC (2016) Review article: consumption of a healthy dietary pattern results in significant reductions in C-reactive protein levels in adults: a meta-analysis. Nutrition Research 36: 391–401
59. Khayyatzadeh, Sayyed Saeid, et al. "A Western dietary pattern is associated with elevated level of high sensitive C-reactive protein among adolescent girls." European journal of clinical investigation 48.4 (2018): e12897.
60. Mehta, Shikhar, et al. "Resveratrol and Curcumin Attenuate Ex Vivo Sugar-Induced Cartilage Glycation, Stiffening, Senescence, and Degeneration." Cartilage (2021): 1947603520988768.
61. Son, Joy, et al. "The effect of athletes' probiotic intake may depend on protein and dietary fiber intake." Nutrients 12.10 (2020): 2947.
62. Rosa S, Gonçalves J, Judas F, Mobasheri A, Lopes C, et al. (2009) Im- paired glucose transporter-1 degradation and increased glucose trans- port and oxidative stress in response to high glucose in chondrocytes from osteoarthritic versus normal human cartilage.
Arthritis Res Ther 11(3): R80.
63. Noble, Emily E., Ted M. Hsu, and Scott E. Kanoski. "Gut to brain dysbiosis: mechanisms linking western diet consumption, the microbiome, and cognitive impairment." Frontiers in behavioral neuroscience 11 (2017): 9.
64. Boer, Cindy G., et al. "Intestinal microbiome composition and its relation to joint pain and inflammation." Nature communications 10.1 (2019): 1-9.
65. Pirozzi, Claudio, et al. "Butyrate modulates inflammation in chondrocytes via GPR43 receptor." Cellular Physiology and Biochemistry 51.1 (2018): 228-243.
66. Berthelot, Jean-Marie, et al. "Cartilage-gut-microbiome axis: a new paradigm for novel therapeutic opportunities in osteoarthritis." RMD open 5.2 (2019): e001037.
67. Ghanim H, Abuaysheh S, Sia CL, Korzeniewski K, Chaudhuri A, Fernandez-Real JM, Dandona P. Increase in plasma endotoxin concentrations and the expression of Toll-like receptors and suppressor of cytokine signaling-3 in mononuclear cells after a high-fat, high-carbohydrate meal: implications for insulin resistance. Diabetes Care. 2009 Dec;32(12):2281-7. doi: 10.2337/dc09-0979. Epub 2009 Sep 15.
68. Rose, Stewart, and Amanda Strombom. "Osteoarthritis Prevention and Treatment with a Plant-Based Diet." Orthopedics and Rheumatology Open Access Journals 15.3 (2019): 76-80

69. Davidson, Rose K., et al. “Identifying chondroprotective diet-derived bioactives and investigating their synergism.” Scientific reports 8.1 (2018): 1-13.
70. Nikawa, Takeshi, Anayt Ulla, and Iori Sakakibara. “Polyphenols and Their Effects on Muscle Atrophy and Muscle Health.” Molecules 26.16 (2021): 4887.
71. Alway, Stephen E. “Antioxidants and Polyphenols Mediate Mitochondrial Mediated Muscle Death Signaling in Sarcopenia.” Nutrition and Skeletal Muscle. Academic Press, 2019. 439-494.
72. Mobasheri, Ali, and Mehdi Shakibaei. “Osteogenic effects of resveratrol in vitro: potential for the prevention and treatment of osteoporosis.” Annals of the New York Academy of Sciences 1290.1 (2013): 59-66.
73. Maleki, Masomeh, et al. “Stabilization of telomere by the antioxidant property of polyphenols: Anti-aging potential.” Life Sciences (2020): 118341.
74. Zanichelli, Fulvia, et al. “Dose-dependent effects of R-sulforaphane isothiocyanate on the biology of human mesenchymal stem cells, at dietary amounts, it promotes cell proliferation and reduces senescence and apoptosis, while at anti-cancer drug doses, it has a cytotoxic effect.” Age 34.2 (2012): 281-293.

Section 2: Plant-based and Vegan Diets in Exercise and Sport

1. Esselstyn, C.B., A plant-based diet and coronary artery disease: a mandate for effective therapy. J Geriatr Cardiol, 2017. 14(5): p. 317-320.
2. Thavamani, A., T.J. Sferra, and S. Sankararaman, Meet the Meat Alternatives: The Value of Alternative Protein Sources. Curr Nutr Rep, 2020. 9(4): p. 346-355.
3. Barzee, T.a.L.C., Zhongli Pan, Ruihong Zhang,, Fungi for future foods. Journal of Future Foods, 2021. 1(1): p. 25-37,.
4. Hemler, E.C. and F.B. Hu, Plant-Based Diets for Personal, Population, and Planetary Health. Adv Nutr, 2019. 10(Suppl_4): p. S275-S283.
5. Panizza, S., If Veganism Is Not a Choice: The Moral Psychology of Possibilities in Animal Ethics. Animals (Basel), 2020. 10(1).
6. Heianza, Y., et al., Healthful plant-based dietary patterns, genetic risk of obesity, and cardiovascular risk in the UK biobank study. Clin Nutr, 2021. 40(7): p. 4694-4701.
7. Li, H., et al., A prospective study of healthful and unhealthful plant-based diet and risk of overall and cause-specific mortality. Eur J Nutr, 2022. 61(1): p. 387-398.
8. Kahleova, H., S. Levin, and N.D. Barnard, Vegetarian Dietary Patterns and Cardiovascular Disease. Prog Cardiovasc Dis, 2018. 61(1): p. 54-61.
9. Lee, K.W., et al., Effects of Vegetarian Diets on Blood Pressure Lowering: A Systematic Review with Meta-Analysis and Trial Sequential Analysis. Nutrients, 2020. 12(6).
10. Kahleova, H., et al., A Plant-Based Dietary Intervention Improves Beta-Cell Function and Insulin Resistance in Overweight Adults: A 16-Week Randomized Clinical Trial. Nutrients, 2018. 10(2).
11. Viguiliouk, E., et al., Effect of vegetarian dietary patterns on cardiometabolic risk factors in diabetes: A systematic review and meta-analysis of randomized controlled trials. Clin Nutr, 2019. 38(3): p. 1133-1145.
12. Li, S.S., et al., Effect of Plant Protein on Blood Lipids: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. J Am Heart Assoc, 2017. 6(12).
13. Catsburg, C., et al., Dietary patterns and breast cancer risk: a study in 2 cohorts. Am J Clin Nutr, 2015. 101(4): p. 817-23.
14. Tantamango-Bartley, Y., et al., Are strict vegetarians protected against prostate cancer? Am J Clin Nutr, 2016. 103(1): p. 153-60.
15. Orlich, M.J., et al., Vegetarian dietary patterns and the risk of colorectal cancers. JAMA Intern Med, 2015. 175(5): p. 767-76.
16. Papier, K., et al., Comparison of Major Protein-Source Foods and Other Food Groups in Meat-Eaters and Non-Meat-Eaters in the EPIC-Oxford Cohort. Nutrients, 2019. 11(4).
17. Hawley, J.A., Microbiota and muscle highway - two way traffic. Nat Rev Endocrinol, 2020. 16(2): p. 71-72.
18. Hughes, R.L. and H.D. Holscher, Fueling Gut Microbes: A Review of the Interaction between Diet, Exercise, and the Gut Microbiota in Athletes. Adv Nutr, 2021. 12(6): p. 2190-2215.
19. Noh, H., et al., Taxonomic Composition and Diversity of the Gut Microbiota in Relation to Habitual Dietary Intake in Korean Adults. Nutrients, 2021. 13(2).
20. Glick-Bauer, M. and M.C. Yeh, The health advantage of a vegan diet: exploring the gut microbiota connection. Nutrients, 2014. 6(11): p. 4822-38.
21. Davani-Davari, D., et al., Prebiotics: Definition, Types, Sources, Mechanisms, and Clinical Applications. Foods, 2019. 8(3).
22. Hills, R.D., Jr., et al., Gut Microbiome: Profound Implications for Diet and Disease. Nutrients, 2019. 11(7).
23. Valdes, A.M., et al., Role of the gut microbiota in nutrition and health. BMJ, 2018. 361: p. k2179.
24. Li, Y., et al., The Role of Microbiome in Insomnia, Circadian Disturbance and Depression. Front Psychiatry, 2018. 9: p. 669.
25. Oliphant, K. and E. Allen-Vercoe, Macronutrient metabolism by the human gut microbiome: major fermentation by-products and their impact on host health. Microbiome, 2019. 7(1): p. 91.
26. Desai, M.S., et al., A Dietary Fiber-Deprived Gut Microbiota Degrades the Colonic Mucus Barrier and Enhances Pathogen Susceptibility. Cell, 2016. 167(5): p. 1339-1353 e21.
27. Russell, W.R., et al., High-protein, reduced-carbohydrate weight-loss diets promote metabolite profiles likely to be detrimental to colonic health. Am J Clin Nutr, 2011. 93(5): p. 1062-72.
28. Cai, J., et al., High animal protein diet and gut microbiota in human health. Crit Rev Food Sci Nutr, 2021: p. 1-13.
29. Sakkas, H., et al., Nutritional Status and the Influence of the Vegan Diet on the Gut Microbiota and Human Health. Medicina (Kaunas), 2020. 56(2).
30. Pugh, J.N., et al., Gastrointestinal symptoms in elite athletes: time to recognise the problem? Br J Sports Med, 2018. 52(8): p. 487-488.
31. Crowson, M.M. and S.A. McClave, Does the Intestinal Microbiome Impact Athletic Performance? Curr Gastroenterol Rep, 2020. 22(11): p. 53.
32. Milajerdi, A., et al., Association of Dietary Fiber, Fruit, and Vegetable Consumption with Risk of Inflammatory Bowel Disease: A Systematic Review and Meta-Analysis. Adv Nutr, 2021. 12(3): p. 735-743.

33. Trapp, D., W. Knez, and W. Sinclair, Could a vegetarian diet reduce exercise-induced oxidative stress? A review of the literature. J Sports Sci, 2010. 28(12): p. 1261-8.
34. Barnard, N.D., et al., Plant-Based Diets for Cardiovascular Safety and Performance in Endurance Sports. Nutrients, 2019. 11(1).
35. Boutros, G.H., et al., Is a vegan diet detrimental to endurance and muscle strength? Eur J Clin Nutr, 2020.
36. Craddock, J.C., Y.C. Probst, and G.E. Peoples, Vegetarian and Omnivorous Nutrition - Comparing Physical Performance. Int J Sport Nutr Exerc Metab, 2016. 26(3): p. 212-20.
37. Meyer, N. and A. Reguant-Closa, "Eat as If You Could Save the Planet and Win!" Sustainability Integration into Nutrition for Exercise and Sport. Nutrients, 2017. 9(4).
38. Durkalec-Michalski, K., et al., Effect of a Four-Week Vegan Diet on Performance, Training Efficiency and Blood Biochemical Indices in CrossFit-Trained Participants. Nutrients, 2022. 14(4).
39. Hevia-Larrain, V., et al., High-Protein Plant-Based Diet Versus a Protein-Matched Omnivorous Diet to Support Resistance Training Adaptations: A Comparison Between Habitual Vegans and Omnivores. Sports Med, 2021. 51(6): p. 1317-1330.
40. Nebl, J., et al., Characterization, dietary habits and nutritional intake of omnivorous, lacto-ovo vegetarian and vegan runners–a pilot study. BMC nutrition, 2019. 5(1): p. 51.
41. Lynch, H.M., C.M. Wharton, and C.S. Johnston, Cardiorespiratory fitness and peak torque differences between vegetarian and omnivore endurance athletes: A cross-sectional study. Nutrients, 2016. 8(11): p. 726.
42. Boutros, G.H., et al., Is a vegan diet detrimental to endurance and muscle strength? Eur J Clin Nutr, 2020. 74(11): p. 1550-1555.
43. Messina, M., et al., No Difference Between the Effects of Supplementing With Soy Protein Versus Animal Protein on Gains in Muscle Mass and Strength in Response to Resistance Exercise. Int J Sport Nutr Exerc Metab, 2018. 28(6): p. 674-685.
44. Lynch, H., C. Johnston, and C. Wharton, Plant-Based Diets: Considerations for Environmental Impact, Protein Quality, and Exercise Performance. Nutrients, 2018. 10(12).
45. Lynch, H.M., et al., No Significant Differences in Muscle Growth and Strength Development When Consuming Soy and Whey Protein Supplements Matched for Leucine Following a 12 Week Resistance Training Program in Men and Women: A Randomized Trial. Int J Environ Res Public Health, 2020. 17(11).
46. Morton, R.W., et al., A systematic review, meta-analysis and meta-regression of the effect of protein supplementation on resistance training-induced gains in muscle mass and strength in healthy adults. Br J Sports Med, 2018. 52(6): p. 376-384.
47. Moon, J.M., et al., Effects of daily 24-gram doses of rice or whey protein on resistance training adaptations in trained males. J Int Soc Sports Nutr, 2020. 17(1): p. 60.
48. Najjar, R.S. and R.G. Feresin, Plant-Based Diets in the Reduction of Body Fat: Physiological Effects and Biochemical Insights. Nutrients, 2019. 11(11).
49. Rizzo, N.S., et al., Nutrient profiles of vegetarian and nonvegetarian dietary patterns. Journal of the Academy of Nutrition and Dietetics, 2013. 113(12): p. 1610-1619.
50. Aragon, A.A., et al., International society of sports nutrition position stand: diets and body composition. J Int Soc Sports Nutr, 2017. 14: p. 16.
51. Stellingwerff, T. and G.R. Cox, Systematic review: Carbohydrate supplementation on exercise performance or capacity of varying durations. Appl Physiol Nutr Metab, 2014. 39(9): p. 998-1011.
52. Shaw, D.M., et al., Effect of a Ketogenic Diet on Submaximal Exercise Capacity and Efficiency in Runners. Med Sci Sports Exerc, 2019. 51(10): p. 2135-2146.
53. Kanter, M., High-Quality Carbohydrates and Physical Performance: Expert Panel Report. Nutr Today, 2018. 53(1): p. 35-39.
54. Yamagata, K., Polyphenols Regulate Endothelial Functions and Reduce the Risk of Cardiovascular Disease. Curr Pharm Des, 2019. 25(22): p. 2443-2458.
55. Seeley, A.D., K.A. Jacobs, and J.F. Signorile, Acute Soy Supplementation Improves 20-km Time Trial Performance, Power, and Speed. Med Sci Sports Exerc, 2020. 52(1): p. 170-177.
56. de Lima Tavares Toscano, L., et al., A single dose of purple grape juice improves physical performance and antioxidant activity in runners: a randomized, crossover, double-blind, placebo study. Eur J Nutr, 2020. 59(7): p. 2997-3007.
57. Upadhyay, S. and M. Dixit, Role of Polyphenols and Other Phytochemicals on Molecular Signaling. Oxid Med Cell Longev, 2015. 2015: p. 504253.
58. Guan, R., et al., A review of dietary phytochemicals and their relation to oxidative stress and human diseases. Chemosphere, 2021. 271: p. 129499.
59. Dernini, S. and E.M. Berry, Mediterranean Diet: From a Healthy Diet to a Sustainable Dietary Pattern. Front Nutr, 2015. 2: p. 15.
60. Cacau, L.T., et al., Development and Validation of an Index Based on EAT-Lancet Recommendations: The Planetary Health Diet Index. Nutrients, 2021. 13(5).
61. Gehring, J., et al., Consumption of Ultra-Processed Foods by Pesco-Vegetarians, Vegetarians, and Vegans: Associations with Duration and Age at Diet Initiation. J Nutr, 2021. 151(1): p. 120-131.
62. Hector, A.J. and S.M. Phillips, Protein Recommendations for Weight Loss in Elite Athletes: A Focus on Body Composition and Performance. Int J Sport Nutr Exerc Metab, 2018. 28(2): p. 170-177.
63. Phillips, S.M., et al., Mixed muscle protein synthesis and breakdown after resistance exercise in humans. Am J Physiol, 1997. 273(1 Pt 1): p. E99-107.
64. Reidy, P.T. and B.B. Rasmussen, Role of Ingested Amino Acids and Protein in the Promotion of Resistance Exercise-Induced Muscle Protein Anabolism. J Nutr, 2016. 146(2): p. 155-83.
65. Hector, A.J., et al., Pronounced energy restriction with elevated protein intake results in no change in proteolysis and reductions in skeletal muscle protein synthesis that are mitigated by resistance exercise. FASEB J, 2018. 32(1): p. 265-275.
66. Witard, O.C., et al., Myofibrillar muscle protein synthesis rates subsequent to a meal in response to increasing doses of whey protein at rest and after resistance exercise. Am J Clin Nutr, 2014. 99(1): p. 86-95.
67. Stokes, T., et al., Recent Perspectives Regarding the Role of Dietary Protein for the Promotion of Muscle Hypertrophy with Resistance Exercise Training. Nutrients, 2018. 10(2).
68. van Vliet, S., N.A. Burd, and L.J. van Loon, The Skeletal Muscle Anabolic Response to Plant- versus Animal-Based Protein Consumption. J Nutr, 2015. 145(9): p. 1981-91.
69. Pinckaers, P.J.M., et al., The Anabolic Response to Plant-Based Protein Ingestion. Sports Med, 2021. 51(Suppl 1): p. 59-74.
70. Sarwar Gilani, G., C. Wu Xiao, and K.A. Cockell, Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. Br J Nutr, 2012. 108 Suppl 2: p. S315-32.
71. Petroski, W. and D.M. Minich, Is There Such a Thing as "Anti-Nutrients"? A Narrative Review of Perceived Problematic Plant Compounds. Nutrients, 2020. 12(10).
72. Schaafsma, G., Advantages and limitations of the protein digestibility-corrected amino acid score (PDCAAS) as a method for evaluating protein quality in human diets. Br J Nutr, 2012. 108 Suppl 2: p. S333-6.
73. Hertzler, S.R., et al., Plant Proteins: Assessing Their Nutritional Quality and Effects on Health and Physical Function. Nutrients, 2020. 12(12).

74. Eggum, B., Comments on report of a joint FAO/WHO expert consultation on protein quality evaluation, Rome 1990. Z Ernahrungswiss, 1991. 30(2): p. 81-8.
75. Guillin, F.M., et al., Real ileal amino acid digestibility of pea protein compared to casein in healthy humans, a randomized trial. Am J Clin Nutr, 2021.
76. Poore, J. and T. Nemecek, Reducing food's environmental impacts through producers and consumers. Science, 2018. 360(6392): p. 987-992.
77. Messina, M., et al., Neither soyfoods nor isoflavones warrant classification as endocrine disruptors: a technical review of the observational and clinical data. Crit Rev Food Sci Nutr, 2021: p. 1-57.
78. McClements, D.J. and L. Grossmann, The science of plant-based foods: Constructing next-generation meat, fish, milk, and egg analogs. Compr Rev Food Sci Food Saf, 2021. 20(4): p. 4049-4100.
79. Pinckaers, P.J.M., et al., No differences in muscle protein synthesis rates following ingestion of wheat protein, milk protein, and their protein blend in healthy, young males. Br J Nutr, 2021. 126(12): p. 1832-1842.
80. Churchward-Venne, T.A., et al., Supplementation of a suboptimal protein dose with leucine or essential amino acids: effects on myofibrillar protein synthesis at rest and following resistance exercise in men. J Physiol, 2012. 590(11): p. 2751-65.
81. Joint, W.H.O.F.A.O.U.N.U.E.C., Protein and amino acid requirements in human nutrition. World Health Organ Tech Rep Ser, 2007(935): p. 1-265, back cover.
82. Gorissen, S.H.M., et al., Protein content and amino acid composition of commercially available plant-based protein isolates. Amino Acids, 2018. 50(12): p. 1685-1695.
83. Phillips, S.M., The impact of protein quality on the promotion of resistance exercise-induced changes in muscle mass. Nutr Metab (Lond), 2016. 13: p. 64.
84. Mariotti, F. and C.D. Gardner, Dietary Protein and Amino Acids in Vegetarian Diets-A Review. Nutrients, 2019. 11(11).
85. Gardner, C.D., et al., Maximizing the intersection of human health and the health of the environment with regard to the amount and type of protein produced and consumed in the United States. Nutr Rev, 2019. 77(4): p. 197-215.
86. Page, J., R.M. Erskine, and N.D. Hopkins, Skeletal muscle properties and vascular function do not differ between healthy, young vegan and omnivorous men. Eur J Sport Sci, 2021: p. 1-10.
87. Li, C., et al., Daily Supplementation With Whey, Soy, or Whey-Soy Blended Protein for 6 Months Maintained Lean Muscle Mass and Physical Performance in Older Adults With Low Lean Mass. J Acad Nutr Diet, 2021. 121(6): p. 1035-1048 e6.
88. Institute, G.F., Plant-based foods in the U.S. are a $7 billion market. 2021.
89. Monteyne, A.J., et al., Mycoprotein ingestion stimulates protein synthesis rates to a greater extent than milk protein in rested and exercised skeletal muscle of healthy young men: a randomized controlled trial. Am J Clin Nutr, 2020. 112(2): p. 318-333.
90. Oikawa, S.Y., et al., Potato Protein Isolate Stimulates Muscle Protein Synthesis at Rest and with Resistance Exercise in Young Women. Nutrients, 2020. 12(5).
91. Thomas, D.T., K.A. Erdman, and L.M. Burke, Position of the academy of nutrition and dietetics, dietitians of canada, and the american college of sports medicine: Nutrition and athletic performance. Journal of the Academy of Nutrition and Dietetics, 2016. 116(3): p. 501-528.
92. Melina, V., W. Craig, and S. Levin, Position of the Academy of Nutrition and Dietetics: Vegetarian Diets. Journal of the Academy of Nutrition and Dietetics, 2016. 116(12): p. 1970-1980.
93. Kim, I.S., C.H. Kim, and W.S. Yang, Physiologically Active Molecules and Functional Properties of Soybeans in Human Health-A Current Perspective. Int J Mol Sci, 2021. 22(8).
94. Jang, C.H., et al., Fermented Soy Products: Beneficial Potential in Neurodegenerative Diseases. Foods, 2021. 10(3).
95. Blanco Mejia, S., et al., A Meta-Analysis of 46 Studies Identified by the FDA Demonstrates that Soy Protein Decreases Circulating LDL and Total Cholesterol Concentrations in Adults. J Nutr, 2019. 149(6): p. 968-981.
96. Jenkins, D.J.A., et al., Cumulative Meta-Analysis of the Soy Effect Over Time. J Am Heart Assoc, 2019. 8(13): p. e012458.
97. Ma, L., et al., Isoflavone Intake and the Risk of Coronary Heart Disease in US Men and Women: Results From 3 Prospective Cohort Studies. Circulation, 2020. 141(14): p. 1127-1137.
98. Reed, K.E., et al., Neither soy nor isoflavone intake affects male reproductive hormones: An expanded and updated meta-analysis of clinical studies. Reprod Toxicol, 2021. 100: p. 60-67.
99. Cunnane, S.C., Problems with essential fatty acids: time for a new paradigm? Prog Lipid Res, 2003. 42(6): p. 544-68.
100. Smith, G.I., et al., Fish oil-derived n-3 PUFA therapy increases muscle mass and function in healthy older adults. Am J Clin Nutr, 2015. 102(1): p. 115-22.
101. McGlory, C., et al., Omega-3 fatty acid supplementation attenuates skeletal muscle disuse atrophy during two weeks of unilateral leg immobilization in healthy young women. FASEB J, 2019. 33(3): p. 4586-4597.
102. VanDusseldorp, T.A., et al., Impact of Varying Dosages of Fish Oil on Recovery and Soreness Following Eccentric Exercise. Nutrients, 2020. 12(8).
103. Tsuchiya, Y., et al., 4-week eicosapentaenoic acid-rich fish oil supplementation partially protects muscular damage following eccentric contractions. J Int Soc Sports Nutr, 2021. 18(1): p. 18.
104. Heileson, J.L. and L.K. Funderburk, The effect of fish oil supplementation on the promotion and preservation of lean body mass, strength, and recovery from physiological stress in young, healthy adults: a systematic review. Nutr Rev, 2020.
105. Murphy, C.H., et al., Does supplementation with leucine-enriched protein alone and in combination with fish-oil-derived n-3 PUFA affect muscle mass, strength, physical performance, and muscle protein synthesis in well-nourished older adults? A randomized, double-blind, placebo-controlled trial. Am J Clin Nutr, 2021. 113(6): p. 1411-1427.
106. Sanders, T.A., DHA status of vegetarians. Prostaglandins Leukot Essent Fatty Acids, 2009. 81(2-3): p. 137-41.
107. Saunders, A.V., B.C. Davis, and M.L. Garg, Omega-3 polyunsaturated fatty acids and vegetarian diets. Med J Aust, 2013. 199(S4): p. S22-6.
108. Metherel, A.H. and R.P. Bazinet, Updates to the n-3 polyunsaturated fatty acid biosynthesis pathway: DHA synthesis rates, tetracosahexaenoic acid and (minimal) retroconversion. Prog Lipid Res, 2019. 76: p. 101008.
109. Welch, A.A., et al., Dietary intake and status of n-3 polyunsaturated fatty acids in a population of fish-eating and non-fish-eating meat-eaters, vegetarians, and vegans and the product-precursor ratio [corrected] of alpha-linolenic acid to long-chain n-3 polyunsaturated fatty acids: results from the EPIC-Norfolk cohort. Am J Clin Nutr, 2010. 92(5): p. 1040-51.
110. Metherel, A.H., et al., Compound-specific isotope analysis reveals no retroconversion of DHA to EPA but substantial conversion of EPA to DHA following supplementation: a randomized control trial. Am J Clin Nutr, 2019. 110(4): p. 823-831.
111. Domenichiello, A.F., A.P. Kitson, and R.P. Bazinet, Is docosahexaenoic acid synthesis from alpha-linolenic acid sufficient to supply the adult brain? Prog Lipid Res, 2015. 59: p. 54-66.

112. Metherel, A.H., et al., Whole-body DHA synthesis-secretion kinetics from plasma eicosapentaenoic acid and alpha-linolenic acid in the free-living rat. Biochim Biophys Acta, 2016. 1861(9 Pt A): p. 997-1004.
113. Burns-Whitmore, B., et al., Alpha-Linolenic and Linoleic Fatty Acids in the Vegan Diet: Do They Require Dietary Reference Intake/Adequate Intake Special Consideration? Nutrients, 2019. 11(10).
114. Hooshmand, B., et al., Association of Vitamin B12, Folate, and Sulfur Amino Acids With Brain Magnetic Resonance Imaging Measures in Older Adults: A Longitudinal Population-Based Study. JAMA Psychiatry, 2016. 73(6): p. 606-13.
115. Nagao, T. and M. Hirokawa, Diagnosis and treatment of macrocytic anemias in adults. J Gen Fam Med, 2017. 18(5): p. 200-204.
116. Hunt, A., D. Harrington, and S. Robinson, Vitamin B12 deficiency. BMJ, 2014. 349: p. g5226.
117. Pawlak, R., S.E. Lester, and T. Babatunde, The prevalence of cobalamin deficiency among vegetarians assessed by serum vitamin B12: a review of literature. Eur J Clin Nutr, 2014. 68(5): p. 541-8.
118. Watanabe, F., et al., Vitamin B(1)(2)-containing plant food sources for vegetarians. Nutrients, 2014. 6(5): p. 1861-73.
119. Medicine, I.I.o. Vitamin B12 Fact Sheet for Health Professionals. 2020; Available from: https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/#en5.
120. Anker, S.D., et al., Ferric carboxymaltose in patients with heart failure and iron deficiency. N Engl J Med, 2009. 361(25): p. 2436-48.
121. Clenin, G., et al., Iron deficiency in sports - definition, influence on performance and therapy. Swiss Med Wkly, 2015. 145: p. w14196.
122. Medicine, I.o., Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. 2001, Washington DC: National Academy Press.
123. Sim, M., et al., Iron considerations for the athlete: a narrative review. Eur J Appl Physiol, 2019. 119(7): p. 1463-1478.
124. DellaValle, D.M., Iron supplementation for female athletes: effects on iron status and performance outcomes. Curr Sports Med Rep, 2013. 12(4): p. 234-9.
125. Hurrell, R. and I. Egli, Iron bioavailability and dietary reference values. Am J Clin Nutr, 2010. 91(5): p. 1461S-1467S.
126. Clarys, P., et al., Comparison of nutritional quality of the vegan, vegetarian, semi-vegetarian, pesco-vegetarian and omnivorous diet. Nutrients, 2014. 6(3): p. 1318-1332.
127. Haider, L.M., et al., The effect of vegetarian diets on iron status in adults: A systematic review and meta-analysis. Crit Rev Food Sci Nutr, 2018. 58(8): p. 1359-1374.
128. Henjum, S., et al., Iron Status of Vegans, Vegetarians and Pescatarians in Norway. Biomolecules, 2021. 11(3).
129. Pawlak, R., J. Berger, and I. Hines, Iron Status of Vegetarian Adults: A Review of Literature. Am J Lifestyle Med, 2018. 12(6): p. 486-498.
130. King, J.C., Zinc: an essential but elusive nutrient. The American journal of clinical nutrition, 2011. 94(2): p. 679S-684S.
131. King, J.C., Zinc: an essential but elusive nutrient. Am J Clin Nutr, 2011. 94(2): p. 679S-84S.
132. Hunt, J.R., Bioavailability of iron, zinc, and other trace minerals from vegetarian diets. The American journal of clinical nutrition, 2003. 78(3): p. 633S-639S.
133. Lönnerdal, B., Zinc and health: current status and future directions. J Nutr, 2000. 130: p. 1378-83.
134. Fuhrman, J. and D.M. Ferreri, Fueling the vegetarian (vegan) athlete. Current Sports Medicine Reports, 2010. 9(4): p. 233-241.
135. Nutrition, S.A.C.o., Statement on Iodine and Health. 2014.
136. Kupper, F.C., et al., Commemorating two centuries of iodine research: an interdisciplinary overview of current research. Angew Chem Int Ed Engl, 2011. 50(49): p. 11598-620.
137. Dasgupta, P.K., Y. Liu, and J.V. Dyke, Iodine nutrition: iodine content of iodized salt in the United States. Environ Sci Technol, 2008. 42(4): p. 1315-23.
138. Eveleigh, E.R., et al., Vegans, Vegetarians, and Omnivores: How Does Dietary Choice Influence Iodine Intake? A Systematic Review. Nutrients, 2020. 12(6).
139. Konig, F., et al., Ten repeat collections for urinary iodine from spot samples or 24-hour samples are needed to reliably estimate individual iodine status in women. J Nutr, 2011. 141(11): p. 2049-54.
140. Medicine, I.o., Dietary Reference Intakes for Calcium and Vitamin D 2011, Washington DC: National Academy of Sciences.
141. Knechtle, B., et al., Vitamin D and Stress Fractures in Sport: Preventive and Therapeutic Measures-A Narrative Review. Medicina (Kaunas), 2021. 57(3).
142. Davey, G.K., et al., EPIC–Oxford: lifestyle characteristics and nutrient intakes in a cohort of 33 883 meat-eaters and 31 546 non meat-eaters in the UK. Public health nutrition, 2003. 6(3): p. 259-268.
143. Thorpe, D.L., et al., Dietary patterns and hip fracture in the Adventist Health Study 2: combined vitamin D and calcium supplementation mitigate increased hip fracture risk among vegans. Am J Clin Nutr, 2021.
144. Maughan, R.J., et al., IOC consensus statement: dietary supplements and the high-performance athlete. International journal of sport nutrition and exercise metabolism, 2018. 28(2): p. 104-125.
145. DeLuca, H.F., Overview of general physiologic features and functions of vitamin D. The American journal of clinical nutrition, 2004. 80(6): p. 1689S-1696S.
146. Larson-Meyer, D.E., Vegetarian and Vegan Diets for Athletic Training and Performance. Sports Science Exchange, 2018. 29(188): p. 1-7.
147. Holick, M.F., Vitamin D deficiency. New England Journal of Medicine, 2007. 357(3): p. 266-281.
148. Chan, J., K. Jaceldo-Siegl, and G.E. Fraser, Serum 25-hydroxyvitamin D status of vegetarians, partial vegetarians, and nonvegetarians: the Adventist Health Study-2. The American journal of clinical nutrition, 2009. 89(5): p. 1686S-1692S.
149. Sato, T., N. Inaba, and T. Yamashita, MK-7 and Its Effects on Bone Quality and Strength. Nutrients, 2020. 12(4).
150. Nakagawa, K., et al., Identification of UBIAD1 as a novel human menaquinone-4 biosynthetic enzyme. Nature, 2010. 468(7320): p. 117-21.
151. Nebl, J., et al., Micronutrient Status of Recreational Runners with Vegetarian or Non-Vegetarian Dietary Patterns. Nutrients, 2019. 11(5).
152. Carvalho, M.B., et al., Taurine Supplementation Increases Post-Exercise Lipid Oxidation at Moderate Intensity in Fasted Healthy Males. Nutrients, 2020. 12(5).

153. Brosnan, J.T. and M.E. Brosnan, The sulfur-containing amino acids: an overview. J Nutr, 2006. 136(6 Suppl): p. 1636S-1640S.
154. Elshorbagy, A.K., et al., Homocysteine, cysteine, and body composition in the Hordaland Homocysteine Study: does cysteine link amino acid and lipid metabolism? Am J Clin Nutr, 2008. 88(3): p. 738-46.
155. Rana, S.K. and T.A. Sanders, Taurine concentrations in the diet, plasma, urine and breast milk of vegans compared with omnivores. Br J Nutr, 1986. 56(1): p. 17-27.
156. Kurtz, J.A., et al., Taurine in sports and exercise. J Int Soc Sports Nutr, 2021. 18(1): p. 39.
157. Maughan, R.J., et al., IOC Consensus Statement: Dietary Supplements and the High-Performance Athlete. Int J Sport Nutr Exerc Metab, 2018. 28(2): p. 104-125.
158. Kreider, R.B., et al., International Society of Sports Nutrition position stand: safety and efficacy of creatine supplementation in exercise, sport, and medicine. J Int Soc Sports Nutr, 2017. 14: p. 18.
159. Walker, J.B., Creatine: biosynthesis, regulation, and function. Adv Enzymol Relat Areas Mol Biol, 1979. 50: p. 177-242.
160. Kaviani, M., K. Shaw, and P.D. Chilibeck, Benefits of Creatine Supplementation for Vegetarians Compared to Omnivorous Athletes: A Systematic Review. Int J Environ Res Public Health, 2020. 17(9).
161. Lukaszuk, J.M., et al., Effect of creatine supplementation and a lacto-ovo-vegetarian diet on muscle creatine concentration. Int J Sport Nutr Exerc Metab, 2002. 12(3): p. 336-48.
162. Burke, D.G., et al., Effect of creatine and weight training on muscle creatine and performance in vegetarians. Med Sci Sports Exerc, 2003. 35(11): p. 1946-55.
163. Roschel, H., et al., Creatine Supplementation and Brain Health. Nutrients, 2021. 13(2).
164. Balestrino, M. and E. Adriano, Beyond sports: Efficacy and safety of creatine supplementation in pathological or paraphysiological conditions of brain and muscle. Med Res Rev, 2019. 39(6): p. 2427-2459.
165. Boldyrev, A.A., G. Aldini, and W. Derave, Physiology and pathophysiology of carnosine. Physiol Rev, 2013. 93(4): p. 1803-45.
166. Harris, R.C., et al., Determinants of muscle carnosine content. Amino Acids, 2012. 43(1): p. 5-12.
167. Grgic, J., et al., International Society of Sports Nutrition position stand: sodium bicarbonate and exercise performance. J Int Soc Sports Nutr, 2021. 18(1): p. 61.
168. Everaert, I., et al., Vegetarianism, female gender and increasing age, but not CNDP1 genotype, are associated with reduced muscle carnosine levels in humans. Amino Acids, 2011. 40(4): p. 1221-9.
169. Willett, W., et al., Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet, 2019. 393(10170): p. 447-492.

Section 3: Fueling, Blood Flow, Inflammation, and Immunity

1. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. J Acad Nutr Diet. 2016;116(3):501-528. doi:10.1016/j.jand.2015.12.006
2. Potgieter S, BScDietetics M. Sport nutrition: A review of the latest guidelines for exercise and sport nutrition from the American College of Sport Nutrition, the International Olympic Committee and the International Society for Sports Nutrition. S Afr J Clin Nutr. 2013;6(26):1. doi: 10.1080/16070658.2013.11734434
3. Wirnitzer KC. Vegan diet in sports and exercise—health benefits and advantages to athletes and physically active people: A narrative review. Int J Sports Exerc Med. 2020;6:165. doi: 10.23937/2469-5718/1510165
4. Trakman GL, Forsyth A, Devlin BL, et al. A systematic review of athletes' and coaches' nutrition knowledge and reflections on the quality of current nutrition knowledge measures. Nutrients. 2016;8(9):570. doi:10.3390/nu8090570
5. Alghannam AF, Ghaith MM, Alhussain MH. Regulation of energy substrate metabolism in endurance exercise. Int J Environ Res Public Health. 2021;18(9):4963. doi:10.3390/ijerph18094963
6. Hargreaves M, Spriet LL. Skeletal muscle energy metabolism during exercise. Nat Metab. 2020;2(9):817-828. doi:10.1038/s42255- 020-0251-4
7. Masson G, Lamarche B. Many non-elite multisport endurance athletes do not meet sports nutrition recommendations for carbohydrates. Appl Physiol Nutr Metab. 2016;41(7):728-734. doi:10.1139/apnm-2015-0599
8. Clark M, Reed DB, Crouse SF, et al. Pre- and post-season dietary intake, body composition, and performance indices of NCAA division I female soccer players. Int J Sport Nutr Exerc Metab. 2003;13(3):303-319. doi:10.1123/ijsnem.13.3.303
9. Nebl J, Schuchardt JP, Wasserfurth P, et al. Characterization, dietary habits and nutritional intake of omnivorous, lacto-ovo vegetarian and vegan runners - a pilot study. BMC Nutr. 2019;5:51. doi:10.1186/s40795-019-0313-8
10. Nunes CL, Matias CN, Santos DA, et al. Characterization and comparison of nutritional intake between preparatory and competitive phase of highly trained athletes. Medicina (Kaunas). 2018;54(3):41. doi:10.3390/medicina54030041
11. Kanter M. High-quality carbohydrates and physical performance: Expert panel report. Nutr Today. 2018;53(1):35-39. doi:10.1097/NT.0000000000000238
12. Jenner SL, Buckley GL, Belski R, et al. Dietary intakes of professional and semi-professional team sport athletes do not meet sport nutrition recommendations-A systematic literature review. Nutrients. 2019;11(5):1160. doi:10.3390/nu11051160
13. Ashtary-Larky D, Bagheri R, Asbaghi O, et al. Effects of resistance training combined with a ketogenic diet on body composition: a systematic review and meta-analysis. Crit Rev Food Sci Nutr. 2021;1-16. doi:10.1080/10408398.2021.1890689
14. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. J Acad Nutr Diet. 2016;116(3):501-528. doi:10.1016/j.jand.2015.12.006
15. Barnard ND, Goldman DM, Loomis JF, et al. Plant-based diets for cardiovascular safety and performance in endurance sports. a. Nutrients. 2019;11(1):130. doi:10.3390/nu11010130
16. Toro R, Mangas A, Quezada M, et al. Influencia de la dieta y el ejercicio en el perfil proteómico de una poblacion deportista.a. Nutrición Hospitalaria. 2014;30(5):1110-7. doi:10.3305/nh.2015.31.5.8828
17. Boutros GH, Landry-Duval MA, Garzon M, et al. Is a vegan diet detrimental to endurance and muscle strength? Eur J Clin Nutr. 2020;74(11):1550-1555. doi:10.1038/s41430-020-0639-y

18. Król W, Price S, Śliż D, et al. A vegan athlete's heart-Is it different? Morphology and function in echocardiography. Diagnostics (Basel). 2020;10(7):477. doi:10.3390/diagnostics10070477
19. Rizzo NS, Sabaté J, Jaceldo-Siegl K, et al. Vegetarian dietary patterns are associated with a lower risk of metabolic syndrome: the Adventist Health Study 2. Diabetes Care. 2011;34(5):1225-1227. doi:10.2337/dc10-1221
20. Turner-McGrievy G, Harris M. Key elements of plant-based diets associated with reduced risk of metabolic syndrome. Curr Diab Rep. 2014;14(9):524. doi:10.1007/s11892-014-0524-y
21. Castro-Barquero S, Ruiz-León AM, Sierra-Pérez M, et al. Dietary strategies for Metabolic Syndrome: A comprehensive review. a. Nutrients. 2020;12(10):2983. doi:10.3390/nu12102983
22. Marrone G, Guerriero C, Palazzetti D, et al. Vegan diet health benefits in Metabolic Syndrome. Nutrients. 2021;13(3):817. doi:10.3390/nu13030817
23. Pistollato F, Battino M. Role of plant-based diets in the prevention and regression of metabolic syndrome and neurodegenerative diseases. Trends in Food Science & Technology. 2014;40(1):62-81. doi:10.1016/j.tifs.2014.07.012
24. El-Sayed MS, Ali N, El-Sayed Ali Z. Haemorheology in exercise and training. Sports Med. 2005;35(8):649-670. doi:10.2165/00007256-200535080-00001
25. Smith MM, Lucas AR, Hamlin RL, et al. Associations among hemorheological factors and maximal oxygen consumption. Is there a role for blood viscosity in explaining athletic performance? Clin Hemorheol Microcirc. 2015;60(4):347-362. doi:10.3233/CH-131708
26. Ernst E, Pietsch L, Matrai A, et al. Blood rheology in vegetarians. Br J Nutr. 1986;56(3):555-560. doi:10.1079/bjn19860136
27. Bae JH, Bassenge E, Kim KB, et al. Postprandial hypertriglyceridemia impairs endothelial function by enhanced oxidant stress. a. Atherosclerosis. 2001;155(2):517-523. doi:10.1016/s0021-9150(00)00601-8
28. Miller M, Beach V, Sorkin JD, et al. Comparative effects of three popular diets on lipids, endothelial function, and C-reactive protein during weight maintenance. J Am Diet Assoc. 2009;109(4):713-717. doi:10.1016/j.jada.2008.12.023
29. Sarabi M, Vessby B, Millgård J, et al. Endothelium-dependent vasodilation is related to the fatty acid composition of serum lipids in healthy subjects. Atherosclerosis. 2001;156(2):349-355. doi:10.1016/s0021-9150(00)00658-4
30. Wang F, Zheng J, Yang B, et al. Effects of vegetarian diets on blood lipids: A systematic review and meta-analysis of randomized controlled trials. J Am Heart Assoc. 2015;4(10):e002408. doi:10.1161/JAHA.115.002408
31. Destiana D, Timan IS. The relationship between hypercholesterolemia as a risk factor for stroke and blood viscosity measured using Digital Microcapillary. Journal of Physics: Conference Series 2018;1073(4):042045. doi:10.1088/1742-6596/1073/4/042045
32. Seki K, Sumino H, Nara M, et al. Relationships between blood rheology and age, body mass index, blood cell count, fibrinogen, and lipids in healthy subjects. Clin Hemorheol Microcirc. 2006;34(3):401-410.
33. Wirnitzer KC. Vegan diet in sports and exercise–Health benefits and advantages to athletes and physically active people: A narrative review. Int J Sports Exerc Med. 2020;6:165. doi:10.23937/2469-5718/1510165
34. Sloop G, Holsworth RE Jr, Weidman JJ, et al. The role of chronic hyperviscosity in vascular disease. Ther Adv Cardiovasc Dis. 2015;9(1):19-25. doi:10.1177/1753944714553226
35. Lin PH, Leslie D, Levine M, et al. Plant-based diet reverses vascular endothelial dysfunction in patients with peripheral arterial disease. Int J Dis Reversal Prev. 2020;2(1):15. doi:10.22230/ijdrp.2020v2n1a53
36. Beavers KM, Brinkley TE, Nicklas BJ. Effect of exercise training on chronic inflammation. Clin Chim Acta. 2010;411(11-12):785-793. doi:10.1016/j.cca.2010.02.069
37. Baker ME, DeCesare KN, Johnson A, et al. Short-term Mediterranean diet improves endurance exercise performance: A randomized-sequence crossover trial. J Am Coll Nutr. 2019;38(7):597-605. doi:10.1080/07315724.2019.1568322
38. Soltani S, Chitsazi MJ, Salehi-Abargouei A. The effect of Dietary Approaches to Stop Hypertension (DASH) on serum inflammatory markers: A systematic review and meta-analysis of randomized trials. Clin Nutr. 2018;37(2):542-550. doi:10.1016/j.clnu.2017.02.018
39. Li Z, Wong A, Henning SM, et al. Hass avocado modulates postprandial vascular reactivity and postprandial inflammatory responses to a hamburger meal in healthy volunteers. Food Funct. 2013;4(3):384-391. doi:10.1039/c2fo30226h
40. Hever J. Plant-based diets: A physician's guide. Perm J. 2016;20(3):15-082. doi:10.7812/TPP/15-082
41. Cheung K, Hume P, Maxwell L. Delayed onset muscle soreness : treatment strategies and performance factors. Sports Med. 2003;33(2):145-64. doi:10.2165/00007256-200333020-00005
42. Carlsen MH, Halvorsen BL, Holte K, et al. The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. Nutr J. 2010;9:3. doi:10.1186/1475-2891-9-3
43. Valtueña S, Pellegrini N, Franzini L, et al. Food selection based on total antioxidant capacity can modify antioxidant intake, systemic inflammation, and liver function without altering markers of oxidative stress. Am J Clin Nutr. 2008;87(5):1290-1297. doi:10.1093/ajcn/87.5.1290
44. Craddock JC, Neale EP, Peoples GE, et al. Vegetarian-based dietary patterns and their relation with inflammatory and immune biomarkers: A systematic review and meta-analysis. Adv Nutr. 2019;10(3):433-451. doi:10.1093/advances/nmy103
45. Craddock JC, Neale EP, Peoples GE, et al. Plant-based eating patterns and endurance performance: A focus on inflammation, oxidative stress and immune responses. Nutr Bull. 2020;45(2):123-32. doi:10.1111/nbu.12427
46. Furman D, Campisi J, Verdin E, et al. Chronic inflammation in the etiology of disease across the life span. Nat Med. 2019;25(12):1822-1832. doi:10.1038/s41591-019-0675-0
47. Haghighatdoost F, Bellissimo N, Totosy de Zepetnek JO, et al. Association of vegetarian diet with inflammatory biomarkers: a systematic review and meta-analysis of observational studies. Public Health Nutr. 2017;20(15):2713-2721. doi:10.1017/S1368980017001768
48. Le LT, Sabaté J. Beyond meatless, the health effects of vegan diets: findings from the Adventist cohorts. Nutrients. 2014;6(6):2131- 2147. doi:10.3390/nu6062131
49. Gleeson M. Can nutrition limit exercise-induced immunodepression?. Nutr Rev. 2006;64(3):119-131. doi:10.1111/j.1753- 4887.2006.tb00195.x
50. Fuhrman J, Ferreri DM. Fueling the vegetarian (vegan) athlete. Curr Sports Med Rep. 2010;9(4):233-241. doi:10.1249/JSR.0b013e3181e93a6f
51. National Antimicrobial Resistance Monitoring System. NARMS integrated report: 2012 - 2013: The National Antimicrobial Resistance Monitoring System: Enteric bacteria. U.S. Food and Drug Administration. 2015.
52. Bhat ZF, Kumar S, Bhat HF. In vitro meat: A future animal-free harvest. Crit Rev Food Sci Nutr. 2017;57(4):782-789. doi:10.1080/10408398.2014.924899
53. Puertollano MA, Puertollano E, de Cienfuegos GÁ, et al. Dietary antioxidants: Immunity and host defense. Curr Top Med Chem. 2011;11(14):1752-1766. doi:10.2174/156802611796235107

54. Eat more fruits and vegetables to improve your immune system. Five or more portions of fruits and vegetables daily significantly increase antibody response. Duke Med Health News. 2013;19(2):5-6
55. Douglas RM, Muirhead TC. Fruit, vegetables and acute respiratory infections. Med J Aust. 1983;1(11):502-503. doi:10.5694/j.1326- 5377.1983.tb136190.x
56. Tuso PJ, Ismail MH, Ha BP, et al. Nutritional update for physicians: plant-based diets. Perm J. 2013;17(2):61-66. doi:10.7812/TPP/12- 085
57. Kim H, Rebholz CM, Hegde S, et al. Plant-based diets, pescatarian diets and COVID-19 severity: A population-based case–control study in six countries. BMJ Nutrition, Prevention & Health. 2021:bmjnph-2021. doi:10.1136/bmjnph-2021-000272

Section 4: Athletes Seeking a Healthy Gut for Optimal Performance

1. Holscher HD. Dietary fiber and prebiotics and the gastrointestinal microbiota. Gut Microbes. 2017;8(2):172-184. doi:10.1080/19490976.2017.1290756
2. Peters HP. Gastrointestinal symptoms in long-distance runners, cyclists, and triathletes: prevalence, medication, and etiology. Am J Gastroenterol. 1999 Jun;94(6):1570-81.doi:10.1111/j.1572-0241.1999.01147.x.
3. FoodData Central. Milk, Fluid, 1% Fat, Without Added Vitamin A and Vitamin D. U.S. Department Agriculture, Agricultural Research Service. https://fdc.nal.usda.gov/fdc-app.html#/food-details/173441/nutrients. Published April 1, 2019. Accessed June 18, 2020.
4. Swagerty DL Jr, Walling AD, Klein RM. Lactose intolerance [published correction appears in Am Fam Physician. 2003 Mar 15;67(6):1195]. Am Fam Physician. 2002;65(9):1845-1850.
5. Dasgupta A, Wahed A. Inborn Errors of Metabolism. In Clinical Chemistry, Immunology and Laboratory Quality Control 1st Edition. San Diego, CA: Elsevier; 2014:213-228. doi:10.1016/B978-0-12-407821-5.00012-7
6. Deng Y, Misselwitz B, Dai N, Fox M. Lactose intolerance in adults: biological mechanism and dietary management. Nutrients. 2015;7(9):8020-8035. doi:10.3390/nu7095380
7. Storhaug CL, Fosse SK, Fadnes LT. Country, regional, and global estimates for lactose malabsorption in adults: a systematic review and meta-analysis. Lancet Gastroenterol Hepatol. 2017;2(10):738-746. doi:10.1016/S2468-1253(17)30154-1
8. Wilder-Smith CH, Olesen SS, Materna A, Drewes AM. Fermentable sugar ingestion, gas production, and gastrointestinal and central nervous system symptoms in patients with functional disorders. Gastroenterology. 2018;155(4):1034-1044.e6. doi:10.1053/j.gastro.2018.07.013
9. Yang J, Deng Y, Chu H, et al. Prevalence and presentation of lactose intolerance and effects on dairy product intake in healthy subjects and patients with irritable bowel syndrome. Clin Gastroenterol Hepatol. 2013;11(3):262-268.e1. doi:10.1016/j.cgh.2012.11.034
10. Zhu Y, Zheng X, Cong Y, et al. Bloating and distention in irritable bowel syndrome: the role of gas production and visceral sensation after lactose ingestion in a population with lactase deficiency. Am J Gastroenterol. 2013;108(9):1516-1525. doi:10.1038/ajg.2013.198
11. Yang J, Fox M, Cong Y, et al. Lactose intolerance in irritable bowel syndrome patients with diarrhoea: the roles of anxiety, activation of the innate mucosal immune system and visceral sensitivity. Aliment Pharmacol Ther. 2014;39(3):302-311. doi:10.1111/apt.12582
12. Killian LA, Chapman-Novakofski KM, Lee SY. Questionnaire on irritable bowel syndrome and symptom management among endurance athletes is valid and reliable. Dig Dis Sci. 2018;63(12):3281-3289. doi:10.1007/s10620-018-5289-8
13. Datz T. Sulfur Amino Acid Restriction Diet Triggers New Blood Vessel Formation in Mice. Harvard T.H. Chan School of Public Health. https://www.hsph.harvard.edu/news/press-releases/sulfur-amino-acid-restriction-diet-blood-vessel-formation. Published March 23, 2018. Accessed April 6, 2020.
14. Yao CK, Rotbart A, Ou JZ, Kalantar-Zadeh K, Muir JG, Gibson PR. Modulation of colonic hydrogen sulfide production by diet and mesalazine utilizing a novel gas- profiling technology. Gut Microbes. 2018;9(6):510-522. doi:10.1080/19490976.2018.1451280
15. Chou CH, Selene J. Hydrogen Sulfide : Human Health Aspects. Geneva, Switzerland: World Health Organization; 2003. Concise International Chemical Assessment Document 53.
16. Wright R, Truelove SC. A controlled therapeutic trial of various diets in ulcerative colitis. Br Med J. 1965;2(5454):138-141. doi:10.1136/bmj.2.5454.138
17. Martin TD, Chan SSM, Hart AR. Environmental factors in the relapse and recurrence of inflammatory bowel disease: a review of the literature. Dig Dis Sci. 2015;60(5):1396-1405. doi:10.1007/s10620-014-3437-3
18. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: nutrition and athletic performance. J Acad Nutr Diet. 2016;116(3):501-528. doi:10.1016/j.jand.2015.12.006
19. Jäger R, Kerksick CM, Campbell BI, et al. International society of sports nutrition position stand: protein and exercise. J Int Soc Sports Nutr. 2017;14(1):20. doi:10.1186/s12970-017-0177-8
20. Vitale K, Getzin A. Nutrition and supplement update for the endurance athlete: review and recommendations. Nutrients. 2019;11(6):1289. doi:10.3390/nu11061289
21. Roediger WE, Moore J, Babidge W. Colonic sulfide in pathogenesis and treatment of ulcerative colitis. Dig Dis Sci. 1997;42(8):1571- 1579.doi:10.1023/a:1018851723920
22. Smith EA, Macfarlane GT. Dissimilatory amino acid metabolism in human colonic bacteria. Anaerobe. 1997;3(5):327-337. doi:10.1006/anae.1997.0121
23. Macfarlane GT, Macfarlane S. Human colonic microbiota: ecology, physiology and metabolic potential of intestinal bacteria. Scand J Gastroenterol Suppl. 1997;222:3-9. doi:10.1080/00365521.1997.11720708
24. Visek WJ. Diet and cell growth modulation by ammonia. Am J Clin Nutr. 1978;31(10 Suppl):S216-S220. doi:10.1093/ajcn/31.10.S216
25. David LA, Maurice CF, Carmody RN, et al. Diet rapidly and reproducibly alters the human gut microbiome. Nature. 2014;505(7484):559-563. doi:10.1038/nature1282
26. Singh RK, Chang HW, Yan D, et al. Influence of diet on the gut microbiome and implications for human health. J Transl Med. 2017;15. doi:10.1186/s12967-017-1175-y
27. De Filippo C, Cavalieri D, Di Paola M, et al. Impact of diet in shaping gut microbiota revealed by a comparative study in children from Europe and rural Africa. Proc Natl Acad Sci U S A. 2010;107(33):14691-14696. doi:10.1073/pnas.1005963107

28. Schwabe RF, Jobin C. The microbiome and cancer. Nat Rev Cancer. 2013;13(11):800-812. doi:10.1038/nrc3610
29. Domínguez R, Cuenca E, Maté-Muñoz JL, et al. Effects of beetroot juice supplementation on cardiorespiratory endurance in athletes. A systematic review. Nutrients. 2017;9(1). doi:10.3390/nu9010043
30. Clifford T, Howatson G, West DJ, Stevenson EJ. The potential benefits of red beetroot supplementation in health and disease. Nutrients. 2015;7(4):2801-2822. doi:10.3390/nu7042801
31. Scalbert A, Johnson IT, Saltmarsh M. Polyphenols: antioxidants and beyond. Am J Clin Nutr. 2005;81(1 Suppl):215S-217S. doi:10.1093/ajcn/81.1.215S
32. Bielli A, Scioli MG, Mazzaglia D, Doldo E, Orlandi A. Antioxidants and vascular health. Life Sci. 2015;143:209-216. doi:10.1016/j.lfs.2015.11.012
33. Tabernero M, Serrano J, Saura-Calixto F. The antioxidant capacity of cocoa products: contribution to the Spanish diet. Int J Food Sci Technol. 2006;41(s1):28-32. doi:10.1111/j.1365-2621.2006.01239.x
34. Serafini M, Testa MF, Villaño D, et al. Antioxidant activity of blueberry fruit is impaired by association with milk. Free Radic Biol Med. 2009;46(6):769-774. doi:10.1016/j.freeradbiomed.2008.11.023
35. Bourassa P, Côté R, Hutchandani S, Samson G, Tajmir-Riahi H-A. The effect of milk alpha-casein on the antioxidant activity of tea polyphenols. J Photochem Photobiol B. 2013;128:43-49. doi:10.1016/j.jphotobiol.2013.07.021

Section 5: Implementation Tools and Resources

1. Shoba G, Joy D, Joseph T, Majeed M, Rajendran R, Srinivas PS. Influence of piperine on the pharmacokinetics of curcumin in animals and human volunteers. Planta Med [Internet]. 1998 -05 [cited Jun 1, 2022];64(4):353-6.
2. Basu A, Fu DX, Wilkinson M, Simmons B, Wu M, Betts NM, Du M, Lyons TJ. Strawberries decrease atherosclerotic markers in subjects with metabolic syndrome. Nutrition research (New York, N.Y.) [Internet]. 2010;30(7):462-9. Available from: https://www.clinicalkey.es/playcontent/1-s2.0-S0271531710001296
3. Ruhee RT, Suzuki K. The integrative role of sulforaphane in preventing inflammation, oxidative stress and fatigue: A review of a potential protective phytochemical. Antioxidants (Basel) [Internet]. 2020 -06-13 [cited Jun 2, 2022];9(6)
4. Li Z, Wong A, Henning SM, Zhang Y, Jones A, Zerlin A, Thames G, Bowerman S, Tseng C, Heber D. Hass avocado modulates postprandial vascular reactivity and postprandial inflammatory responses to a hamburger meal in healthy volunteers. Food & function [Internet]. 2013 Feb 26,;4(3):384-91. Available from: https://www.ncbi.nlm.nih.gov/pubmed/23196671
5. Higdon JV, Frei B. Tea catechins and polyphenols: Health effects, metabolism, and antioxidant functions. Crit Rev Food Sci Nutr [Internet]. 2003 [cited Jun 2, 2022];43(1):89-143.
6. Liu A, Tipton R, Pan W, Finley J, Prudente A, Karki N, Losso J, Greenway F. Tart cherry juice increases sleep time in older adults with insomnia (830.9). The FASEB Journal [Internet]. 2014;28:830.9. Available from: https://doi-org.une.idm.oclc.org/10.1096/fasebj.28.1_supplement.830.9
7. Zick SM, Wright BD, Sen A, Arnedt JT. Preliminary examination of the efficacy and safety of a standardized chamomile extract for chronic primary insomnia: A randomized placebo-controlled pilot study. BMC Complement Altern Med [Internet]. 2011 -9-22 [cited Jun 1, 2022];11:78. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3198755/
8. Patrick RP, Ames BN. Vitamin D and the omega-3 fatty acids control serotonin synthesis and action, part 2: Relevance for ADHD, bipolar disorder, schizophrenia, and impulsive behavior. The FASEB Journal [Internet]. 2015;29(6):2207-22. Available from: https://doi-org.une.idm.oclc.org/10.1096/fj.14-268342 9. Abbasi B, Kimiagar M, Sadeghniiat K, Shirazi MM, Hedayati M, Rashidkhani B. The effect of magnesium supplementation on primary insomnia in elderly: A double-blind placebo-controlled clinical trial. J Res Med Sci [Internet]. 2012 -12 [cited Jun 1, 2022];17(12):1161-9. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3703169/
10. Binks H, E Vincent G, Gupta C, Irwin C, Khalesi S. Effects of diet on sleep: A narrative review. Nutrients [Internet]. 2020 Mar 27,;12(4):936. Available from: https://www.ncbi.nlm.nih.gov/pubmed/32230944
11. Alvarez-Collazo J, Alonso-Carbajo L, López-Medina AI, Alpizar YA, Tajada S, Nilius B, Voets T, López-López JR, Talavera K, Pérez-García MT, Alvarez JL. Cinnamaldehyde inhibits L-type calcium channels in mouse ventricular cardiomyocytes and vascular smooth muscle cells. Pflugers Arch [Internet]. 2014 -11 [cited Jun 1, 2022];466(11):2089-99.
12. Akilen R, Pimlott Z, Tsiami A, Robinson N. Effect of short-term administration of cinnamon on blood pressure in patients with prediabetes and type 2 diabetes. Nutrition [Internet]. 2013 -10 [cited Jun 1, 2022];29(10):1192-6.
13. Mahdavi-Roshan M, Mirmiran P, Arjmand M, Nasrollahzadeh J. Effects of garlic on brachial endothelial function and capacity of plasma to mediate cholesterol efflux in patients with coronary artery disease. Anatolian Journal of Cardiology [Internet]. 2017 Aug;18(2):116-21. Available from: https://www.ncbi.nlm.nih.gov/pubmed/28554988
14. Domínguez R, Cuenca E, Maté-Muñoz JL, García-Fernández P, Serra-Paya N, Estevan MCL, Herreros PV, Garnacho-Castaño MV. Effects of beetroot juice supplementation on cardiorespiratory endurance in athletes. A systematic review. Nutrients [Internet]. 2017 -1-06 [cited Jun 2, 2022];9(1) Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5295087/
15. Buscemi S, Rosafio G, Arcoleo G, Mattina A, Canino B, Montana M, Verga S, Rini G. Effects of red orange juice intake on endothelial function and inflammatory markers in adult subjects with increased cardiovascular risk. Am J Clin Nutr [Internet]. 2012 -05 [cited Jun 1, 2022];95(5):1089-95.
16. Jovanovski E, Bosco L, Khan K, Au-Yeung F, Ho H, Zurbau A, Jenkins AL, Vuksan V. Effect of spinach, a high dietary nitrate source, on arterial stiffness and related hemodynamic measures: A randomized, controlled trial in healthy adults. Clinical Nutrition Research [Internet]. 2015 Jul;4(3):160-7. Available from: https://www.ncbi.nlm.nih.gov/pubmed/26251834
17. Sobko T, Marcus C, Govoni M, Kamiya S. Dietary nitrate in japanese traditional foods lowers diastolic blood pressure in healthy volunteers. Nitric Oxide [Internet]. 2010;22(2):136-40. Available from: https://www-sciencedirect-com.une.idm.oclc.org/science/article/pii/S108986030900127X
18. Carlsen MH, Halvorsen BL, Holte K, Bøhn SK, Dragland S, Sampson L, Willey C, Senoo H, Umezono Y, Sanada C, Barikmo I, Berhe N, Willett WC, Phillips KM, Jacobs J, David R, Blomhoff R. The total antioxidant content of more than 3100 foods, bever ages, spices, herbs and supplements used worldwide. Nutrition journal [Internet]. 2010 Jan 22,;9(1):3. Available from: https://www.ncbi.nlm.nih.gov/pubmed/20096093
19. Callaway JC. Hempseed as a nutritional resource: An overview. In: [Internet]; 2004Dordrecht: Springer; 2004. p. 65-72.Available from: https://search.proquest.com/docview/741251656 DOI: 10.1007/s10681-004-4811-6

This Playbook could be the beginning of something really big for you. Whether you're a coach, a dietitian, or an athlete, the Playbook demonstrates the power of plant-based fuel to amplify athletic performance. We go deep on nutrition science and the physiological benefits of a plant-based diet, optimized for athletic performance. Section 5 cuts to the chase with a selection of field-tested tools and resources for meal planning and other practical aspects of implementing plant-based nutrition.

You can find more recipes, success stories from world-class plant-based athletes, and even more helpful resources at Switch4Good.org. If you would like to speak with any of the Playbook authors, simply email plantbasedplaybook@switch4good.org and we will make it happen.

Let the plant-based games begin!