Are there Effective Vegan-Friendly Supplements for Optimizing Health and Sports Performance? a Narrative Review

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Alvaro Vergara Nieto
Universidad del Desarrollo

Andres Halabi
Andrés Bello University

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REVIEW

Are there Effective Vegan-Friendly Supplements for Optimizing Health and Sports Performance? a Narrative Review

Álvaro Vergara A. Nieto[2,4] · Andrés Halabi Diaz[1,2,3] · Millaray Hernández[2]

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Abstract

Purpose of Review Veganism, characterized by the exclusion of all animal-derived products, has grown in popularity due to ethical, environmental, and health considerations. However, vegan athletes often face unique nutritional challenges related to dietary deficiencies of critical nutrients such as proteins, vitamin B12, iron, calcium, and omega-3 fatty acids, among others. This narrative review aims to explore the efficacy and benefits of vegan-friendly supplements specifically tailored to athletic performance, focusing on essential micronutrients, ergogenic aids, and nutrient bioavailability.

Recent Findings Nineteen key supplements are discussed, including protein powders, creatine, beta-alanine, caffeine, vitamin B12, vitamin D, omega-3 fatty acids, zinc, calcium, iron, iodine, vitamin K2, selenium, probiotics, nitrates, electrolytes (including sodium and potassium), taurine, vitamin A, and magnesium. Evidence suggests that the integration of these supplements into personalized nutrition plans can bridge dietary gaps while addressing specific performance needs, potentially leveling the competitive field for vegan athletes. Recent studies also highlight research gaps in sex-specific needs, synergistic effects, and strategies to enhance the bioavailability of nutrients from whole foods.

Summary Vegan diets, while conferring various benefits, require careful consideration of nutrient intake for athletes seeking optimal performance. Personalized biochemical assessments should be considered when possible for tailoring specific nutritional guidelines for each case. This narrative review provides practical guidelines for clinicians, nutritionists, trainers, sports scientists, and athletes to design personalized supplementation strategies that address common nutritional shortfalls, enhance performance, and serve as a foundation for future research in vegan sports nutrition.

Keywords Sports · Performance · Deficiencies · Vegan · Supplementation · Health · Metabolism · Essential Micronutrients

Introduction

Veganism, a lifestyle excluding all animal-derived products, is driven by ethical concerns for animal welfare, environmental awareness, and health benefits. Its adoption has grown significantly, particularly in developed countries, with over 3% of the global population following a vegan diet. Despite its benefits, veganism poses nutritional challenges, especially for active individuals and athletes, whose higher nutritional needs may risk deficiencies in nutrients like vitamin B12, iron, zinc, calcium, and omega-3 fatty acids. Supplements are essential to address these gaps [1–3]. It is critical in this context to properly distinguish between vegan and vegetarians, with the latter usually incorporating eggs and milk products to diet [4, 5].

Popular sports supplements like protein powders, creatine, and antioxidants enhance performance and recovery but often include animal-based ingredients. Vegan

✉ Andrés Halabi Diaz
a.halabidiaz@uandresbello.edu

1 Departamento de Ciencias Químicas, Facultad de Ciencias Exactas, Universidad Andres Bello, Avenida Republica 275, 8370146 Santiago, Chile

2 Departamento de Investigación y Desarrollo, Good Research and Science (GRS), Avenida Ramón Picarte 780, 5090000 Valdivia, Chile

3 Departamento de I+D+I, CatchPredict SpA, Avenida Ramón Picarte 780, 5090000 Valdivia, Chile

4 Facultad de Ciencias de La Salud, Escuela de Nutrición y Dietética, Universidad del Desarrollo, Ainavillo 456, 4070001 Concepción, Chile

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formulations must ensure quality, efficacy, and bioequivalence to non-vegan alternatives. Factors like consumption timing, bioavailability, and nutrient interactions are key. For instance, plant-based omega-3 sources like algae oil offer alternatives but face efficacy debates compared to fish or krill-derived options. Similar issues have emerged for protein powders and others [6–8].

This narrative review examines vegan supplements' impact on health and performance, emphasizing their development, efficacy, and differences from non-vegan versions. It identifies improvement areas and research opportunities to optimize vegan athletes' health and performance.

This review should serve both clinicians and athletes for properly developing their specialized nutritional protocols when needing to combine a vegan diet with high sports performance.

A summary of all the nutrients and supplements covered in this review is presented in Table 1. Each supplement is thoroughly discussed in their own section.

Protein Powders

Protein shakes are widely used to support strength development and muscle hypertrophy, especially among athletes engaged in resistance training. Traditionally, animal-based proteins (e.g., whey and casein) were considered superior due to their high leucine content and essential amino acid profile. However, recent studies indicate that, under conditions of adequate protein intake (≥ 1.8 g/kg/day), plant-based proteins—such as mycoprotein, pea, soy, and mung bean—can promote muscle protein synthesis (MPS) comparably to animal proteins [9, 10]. This is particularly relevant for vegan athletes, who can achieve similar muscle gains with well-planned diets supplemented with high-quality plant proteins [11, 12]. Generally speaking, a good protein powder supplement for muscle development should have all 9 essential amino acids, over 70% total protein purity and contain around 3 g of L-Leucine, 1 g of Isoleucine and 1 g of Valine per serving (even though other Leucine prevalent ratios may also be anabolic) [13], as those are the primary amino acids involved in MPS (usually called BCAAs).

Key Considerations for Plant-Based Protein Supplementation

- **Adequate Intake**: Athletes should target 1.6–2.2 g of protein/kg body weight/day. Given lower digestibility and essential amino acid content in plant proteins, doses of 30–40 g per meal help compensate for any shortfall [14].
- **Protein Quality**: Combining different plant proteins enhances the overall amino acid profile, making it easier to meet requirements for leucine and other essential amino acids [11].
- **Timing and Distribution**: Distributing total protein intake across 3–5 meals daily, each supplying at least 0.4 g protein/kg, maximizes MPS and minimizes muscle breakdown [12].
- **Post-Workout and Evening Intake**: Consuming protein soon after exercise, as well as before sleep, supports recovery, muscle repair, and adaptation processes [11].
- **Synergy with Carbohydrates**: Plant-based protein intake combined with carbohydrates post-training can further optimize absorption and enhance MPS [6].

Creatine

Creatine, found primarily in animal muscle, is a well-researched ergogenic aid known for its capacity to boost muscular strength, power, and recovery. Beyond enhancing performance, creatine supports muscle recovery, reduces inflammation, and may mitigate cellular damage induced by intense exercise [15, 16]. Because it is absent from vegan diets, vegans often have lower baseline creatine levels—an issue that can be significantly improved through supplementation [17, 18]. Creatine works by elevating muscular phosphocreatine stores, which are crucial for rapid ATP replenishment during high-intensity, short-duration activities. For vegan athletes, creatine supplementation is necessary to bridge dietary gaps, resulting in notable gains in physical performance and cognition. Almost the entirety of commercially available Creatine supplements is synthetic and therefore vegan-friendly. The most researched and recommended form is Creatine Monohydrate, an odor and tasteless white powder.

Key Considerations for Plant-Based Creatine Supplementation

- **Baseline Deficit and General Health**: Vegans can experience an amplified response to creatine supplementation due to initially low muscle creatine levels [17]. Creatine is a great ally for both muscular and neurological health and performance [19].
- **Dosage Protocols**: A typical loading phase (20 g/day for 5–7 days, split into four doses) followed by a maintenance dose (3–5 g/day) quickly saturates muscle creatine stores. Alternatively, a steady 3 g/day achieves similar results over a longer period [15, 16].
- **Carbohydrate Synergy**: Co-ingestion of creatine with carbohydrates can further enhance uptake and cellular incorporation, an important consideration both for vegans and omnivorous athletes [17, 18].

Table 1 Summarized information for recommended supplements for vegans. 10 out of 19 nutrients are considered essential and should be supplemented in the vegan population in general. All 19 supplements are recommended for vegan athletes wanting to maximize their performance

Supplement	Dosage	Timing	Preffered Sources or Types	Effect
Plant Proteins	1.6–2.2 g/kg/day (30–40 g per meal)	Distributed across 3–5 meals/day; post-workout	Mycoprotein, pea protein, or soy protein	Supports protein synthesis, hypertrophy, and recovery
Creatine	3–5 g/day (maintenance); 20 g/day (loading phase)	Post-workout; combined with carbohydrates	Creatine monohydrate	Increases strength, power, and muscle recovery
Omega-3 (DHA/EPA)	250–500 mg/day (general); 2–4 g/day (specific)	Anytime with meals	Microalgae oil	Reduces inflammation, supports cardiovascular and brain health, and improves muscle recovery
Beta-Alanine	4–6 g/day (divided into 1–1.6 g doses)	Close to workout for adherence	Beta-alanine in powder or sustained-release capsules	Muscle buffering, delayed fatigue, improved energy metabolism and improved endurance
Vitamin B12	250 µg/day or 2500 µg/week	Anytime	Cyanocobalamin or methylcobalamin	Prevents anemia, supports cognition, and enhances hemoglobin synthesis
Vitamin D	2000–5000 IU/day	With meals rich in healthy fats	Cholecalciferol (D3)	Bone health, immunity, and muscle recovery
Iron	30–100 mg/day (with Vitamin C)	Anytime, preferably with Vitamin C	Ferrous sulfate, gluconate, or fumarate	Oxygen transport, anemia prevention, and energy metabolism
Zinc	20–40 mg/day	Anytime	Zinc lactate	Muscle regeneration and immune support
Probiotics	At least 1×10^9 CFU/day	With meals	Lactobacillus and Bifidobacterium strains	Nutrient absorption, reduced inflammation, and gut health
Nitrates	300–600 mg/day	2–3 h before exercise	Beetroot juice or concentrated supplements	Enhanced metabolic efficiency and exercise tolerance
Magnesium	300–450 mg/day	Before or after exercise based on need	Magnesium citrate or malate	Energy production, hydration balance, and muscle recovery
Taurine	1–6 g/day (acute: 2–3 g before exercise)	1–2 h before exercise	Taurine powder or capsules	Reduces oxidative damage, improves recovery, and supports endurance and power output
Calcium	min. 1000–1200 mg/day	Ideally split in smaller doses throughout the day, preferably with Vitamin D	Calcium carbonate or citrate	Reduces fracture risk and maintains bone density, supports recovery and musculoskeletal health
Caffeine	3–6 $mg/kg_{bodyweight}$	30–60 min before exercise, ideally not before bed time	Pure caffeine powder or capsules	Reduces fatigue perception, boosts physical and mental performance, promotes the use of fatty acids during exercise
Iodine	150 µg/day for adults, 250 µg/day for pregnant women	Anytime, with meals	Potassium iodide salt	Synthesis of T3/T4 hormones, supports metabolism, muscular and neurological health
Vitamin K2	90–200 µg/day for adults	Anytime, preferably with Vitamin D and calcium	Vitamin K2 MK-7 supplements	Reduces fracture risk and maintains bone density, supports recovery and musculoskeletal health
Selenium	55 µg/day	Anytime, preferably with Vitamin E and Zinc	Selenium salts or Selenium enriched yeasts	Supports T3/T4 hormonal system and metabolism, muscle synthesis and energy usage

Table 1 (continued)

Supplement	Dosage	Timing	Preffered Sources or Types	Effect
Electrolytes	300–600 mg/day of Sodium, 3500–4700 mg/day of Potassium, and 300–600 mg per hour of Magnesium	During and post-intense exercise	Electrolyte tables or sports beverages	Keeping of hydration levels stable
Vitamin A	700–900 µg/day	With meals	Liposomal Vitamin A in capsules	Reduces oxidative damage, improves recovery, and supports musculoskeletal health and immune system

- **Strength and Hypertrophy**: Research consistently shows significant improvements in muscle strength, power, and lean mass with creatine supplementation [15, 20].
- **Recovery and Inflammation**: Creatine mitigates muscle damage and inflammation, contributing to faster recovery times and maintaining an anabolic environment conducive to muscle repair [15, 16].

Beta-Alanine

Beta-alanine, a non-essential amino acid, is a key precursor to carnosine, which buffers hydrogen ions (H^+) and delays muscle fatigue during high-intensity anaerobic activities [21, 22]. Because natural dietary sources (e.g., meat and poultry) are absent from vegan diets, supplementation becomes particularly important for vegan athletes. Studies show that increasing muscle carnosine levels via beta-alanine supplementation not only improves fatigue resistance in activities lasting 60 to 240 s—like cycling, mid-distance running, and weightlifting—but also provides antioxidant protection [23–25]. Therefore, beta-alanine supplementation is a vital tool for vegan athletes aiming to maximize physical and potentially cognitive performance. As with Creatine, beta-alanine is mostly vegan-friendly as a synthetic product. Outside of pure beta-alanine white powdered supplements, this compound is also widely used in pre-workout (energetic stimulant mixes) formulas.

Key Considerations for Plant-Based Beta-Alanine Supplementation

- **Lower Baseline Levels:** Vegans typically have reduced muscle carnosine concentrations. Supplementation can result in greater relative gains compared to omnivores, enhancing buffering capacity and athletic performance [22].
- **Dosage and Timing:** A daily dose of 4–6 g for at least 4 weeks can increase carnosine by 60–80%. Dividing doses into smaller servings (1–1.6 g) or using sustained-release forms helps reduce side effects such as paresthesia [22, 23, 25].
- **Cognitive and Recovery Benefits:** Elevated carnosine levels may have antioxidant, antiglycation, and potential cognitive advantages, which are especially beneficial for athletes engaged in intensive training [21].
- **Potential Uncomfortable Side Effects:** beta-alanine is known to cause paresthesia to some users, a side effect usually described as an "itch" covering most of the body. Some users appear to be more sensitive to others. Proper dosage practice may help prevent this [22, 23, 25].

Caffeine

Caffeine is among the most widely used ergogenic aids due to its ability to enhance both physical and cognitive performance by antagonizing adenosine receptors. This mechanism reduces fatigue perception, stimulates the central nervous system, and promotes the utilization of fatty acids during exercise [26]. Research indicates that caffeine supplementation benefits aerobic capacity, boosting endurance in prolonged exercise, as well as anaerobic performance by increasing strength and power output [27]. Vegan athletes experience similar benefits to omnivores when consuming 3–6 mg/kg of caffeine about 30–60 min pre-exercise [28]. Well planned caffeine supplementation can help bridge any ergogenic gaps in plant-based diets, enabling vegan athletes to achieve peak performance.

Key Considerations for Plant-Based Beta-Alanine Supplementation

- **Dosing and Formats**: Various caffeine delivery methods—gum, capsules, powders, or energy drinks—offer versatility in timing and dose. Caffeine gum, in particular, yields a faster response via sublingual absorption, beneficial for quick performance enhancement [29]. For vegans, these formats are compatible with a plant-based diet and enable customized intake to meet sport-specific demands [26]. Ideally 3–6 $mg/kg_{bodyweight}$ of caffeine about 30–60 min pre-exercise.
- **Timing and Recovery**: Ingesting caffeine 30–60 min before exercise significantly improves endurance, strength, and time to exhaustion [30]. However, late-day use may disrupt sleep—an issue for athletes training in the evening [31, 32]. While caffeine can aid recovery by reducing muscle soreness and speeding up recuperation, excessive doses may negatively impact heart rate variability and prolong sympathetic activation, thus hindering active recovery [33].
- **Individual Variability**: Genetic differences, particularly in the CYP1A2 gene, influence caffeine metabolism. Slow metabolizers may experience adverse effects such as anxiety or insomnia, while fast metabolizers typically gain more pronounced ergogenic benefits [34]. These factors apply equally to vegan athletes, who should adjust their dosage to avoid side effects and optimize performance.

B12 Vitamin

Vitamin B12 (cobalamin) is an essential micronutrient involved in DNA synthesis, red blood cell formation, and neuronal function. Vegan diets exclude animal-based foods, posing a major challenge in meeting B12 needs; consequently, supplementation or consumption of fortified foods is crucial to prevent deficiencies [6, 35]. B12 deficiency can lead to megaloblastic anemia, neuropathy, cognitive impairment, and cardiovascular issues related to elevated homocysteine levels [35, 36]. Epidemiological studies indicate that up to 50% of vegans have suboptimal B12 levels, highlighting the need for targeted strategies [6, 35].

Key Considerations for Plant-Based Vitamin B12 Supplementation

- **Sources in Vegan Diets:** Fortified foods like plant-based milk, cereals, and nutritional yeast are primary B12 sources for vegans. A more effective approach is in the form of direct supplementation; where cyanocobalamin is the most widely studied and stable form, while methyl cobalamin may be advantageous in specific metabolic dysfunctions [37].
- **Recommended Dosages:** A daily dose of 250 µg or a weekly dose of 2500 µg effectively maintains adequate B12 levels. These regimens are particularly important for pregnant women, lactating mothers, and older adults. Regular blood tests to check serum B12 levels are recommended to ensure long-term sufficiency. Other effective alternatives are B12 injections which usually contain concentrations of 10.000 mg [38–40].
- **Importance in Athletic Performance:** B12 is essential for hemoglobin synthesis. Inadequate levels can reduce aerobic capacity and hinder post-exercise recovery. Supplementation in vegan athletes enables performance comparable to that of omnivore counterparts [41].
- **Individual Factors:** Age, physical activity level, and intestinal absorption can influence individual B12 requirements, necessitating tailored dietary and supplementation strategies [42].

Vitamin D

Vitamin D is a crucial nutrient for bone health, immune function, and muscle performance, yet it is often lacking in vegan diets due to limited natural plant-based sources [43, 44]. While vitamin D2 (ergocalciferol) can be obtained from UV-exposed mushrooms, vitamin D3 (colecalciferol) is primarily sourced from animal-based foods (e.g., fatty fish, eggs). In vegan populations, low dietary intake of vitamin D3 and insufficient sunlight exposure—particularly in higher latitudes or during low-UV seasons—significantly increase the risk of deficiency [45, 46]. Regarding sports, supplementation with vitamin D3 during winter significantly improved serum 25(OH)D levels, muscle strength, and functional capacity in young soccer players [47]. Similarly, high-dose vitamin D increased aerobic capacity and metabolic efficiency in endurance athletes [48].

Key Considerations for Plant-Based Vitamin D Supplementation

- **Bone Health:** Inadequate vitamin D levels lead to conditions such as osteoporosis and osteomalacia, with older adults at heightened risk for falls, muscle weakness, and fractures [44]. Supplementing together with calcium enhances bone health and can help prevent fractures, particularly in vulnerable groups. [3]
- **Athletic Performance:** Studies report that low vitamin D can compromise muscle strength, aerobic capacity, and recovery in athletes [3, 49]. Sufficient vitamin D levels also support immune function, potentially reducing injury and illness in athletes [50].
- **Daily Intake:** Research suggests a safe and effective range of 2000–5000 IU/day of vitamin D3 for maintaining serum 25(OH)D levels above 30 ng/mL [48, 49].
- **Monitoring Levels**: Regular serum 25(OH)D testing is essential for athletes—especially vegans—to adjust supplementation to individual needs and environmental conditions [46].

Omega-3 Unsaturated Fatty Acids

Omega-3 fatty acids play a critical role in cardiovascular, neurological, and immune function, but vegan diets lack traditional sources such as fatty fish. Instead, they rely on alpha-linolenic acid (ALA) from flaxseed, chia, and walnuts; however, ALA's conversion to EPA and DHA in humans is quite limited (under 10% for EPA and under 1% for DHA) due to factors like enzyme competition with omega-6 fats, micronutrient deficiencies (e.g., zinc, iron), and genetic variants [45, 51]. Omega-3 fatty acids—especially EPA and DHA—are vital for overall health and sports performance. In vegan populations, microalgae supplements bridge the gap left by the absence of fish-based omega-3 s providing effective DHA sources [52, 53]. Future research should refine supplementation strategies and assess the long-term impacts of omega-3 use in vegan populations as well as providing novel vegan EPA sources [53, 54]. As vegans already have many of the EPA associated benefits solely from their diet (for example reduced inflammation due to higher fiber and antioxidants consumption), supplementing only DHA is still an effective approach. Nevertheless, there is an increasing need of developing new microalgae sources high in both EPA and DHA [53, 55].

Key Considerations for Plant-Based Omega-3 Supplementation

- **Dosing Recommendations**: 3–5 g/day of EPA + DHA has been linked to reduced muscle soreness and IL-6 levels after intense workouts, particularly benefiting vegan athletes [56, 57]. Consuming just DHA on its own is also enough for most vegan population for this effects. For vegans, microalgae-based DHA provides an effective, sustainable solution. Generally recommended doses are 250–500 mg/day for general health and 2–4 g/day for targeted applications like lowering blood triglycerides or supporting cognitive health [58].
- **Impact on Health and Performance:** DHA makes up ~ 40% of the brain's polyunsaturated fatty acids, aiding synaptic plasticity and cognitive function. Supplementation aids developing brains and also protects against neurodegenerative diseases in older adults [59, 60]. Even though most research focuses on high-dose EPA [61, 62], vegan microalgae supplements high in DHA can similarly improve blood pressure and vascular elasticity [53].

Zinc

Zinc is an essential trace element involved in protein synthesis, immune regulation, and energy metabolism. Its role in vegan athletes is particularly significant due to limited plant-based availability and the mineral's direct impact on physical performance and muscle recovery [63, 64]. Main vegan dietary sources—whole grains, seeds, nuts, and legumes—are rich in phytates, which reduce zinc bioavailability and raise deficiency risks for high-demand groups such as athletes [65, 66]. Organic supplements (e.g., zinc lactate) often show superior absorption compared to inorganic forms [67].

Adequate zinc status supports muscle repair, antioxidant defenses, and immune function [63, 68]. Sufficient zinc also helps maintain gut barrier integrity, reducing inflammation and enhancing nutrient absorption [69]. Research indicates zinc supplementation can improve satellite cell proliferation, modulate key immune responses, and lower inflammatory markers, thereby supporting muscle recovery following endurance exercise [67, 70].

Key Considerations for Zinc Supplementation

- **Bioavailability and Sources:** Zinc lactate and other organic salts typically show enhanced uptake compared to inorganic forms [67]. High-phytate foods (e.g., grains, legumes) can hinder absorption [65, 66]. Proper supplementation and food intake timing are therefore essential for securing proper zinc absorption.
- **Dosing Recommendations:** Factors such as training intensity, dietary patterns, and environmental conditions influence zinc requirements. 20–40 mg/day is generally advised to prevent deficiencies and avoid adverse effects from excessive intake [68].
- **Impact on Health and Performance:** Adequate zinc promotes muscle regeneration, immune defense, and

reduced inflammation—key for athletes with intense training regimens. Zinc's role in maintaining intestinal barrier function further aids nutrient assimilation and inflammation control [63, 66]. Proper Zinc levels are essential for MPS and muscular metabolism. Effective Zinc supplementation could aid developing humans, athletes and older persons to enhance their muscular development, strength and overall functionality [63, 70].

Calcium

Calcium is an essential mineral for bone formation and maintenance, muscle function, and nerve transmission. Within vegan diets, calcium intake can be challenging due to limited plant-based sources and reduced bioavailability caused by phytates and oxalates [71, 72]. Calcium deficiency can lead to osteoporosis, reduced bone mineral density, and an elevated risk of fractures, issues particularly pertinent to vegan athletes [73].

Vegan sources of calcium include leafy greens, almonds, fortified tofu, and enriched plant milks [71]. However, supplementation—commonly in forms like calcium carbonate or citrate—often becomes necessary to ensure adequate intake. When combined with vitamin D, calcium absorption and bone retention improve significantly [74]. Recent studies underscore the efficacy of fractionated calcium dosing throughout the day to optimize absorption and minimize gastrointestinal side effects [73]. Adequate calcium status supports not only bone health but also overall athletic performance, particularly in preventing injury and enhancing post-exercise recovery [72].

Key Considerations for Calcium Supplementation

- **Bioavailability and Dietary Sources**: Plant-based calcium can be hindered by phytates and oxalates, reducing absorption. Leafy greens, almonds, fortified tofu, and enriched plant milks can help meet calcium requirements but often need to be combined with supplementation. Calcium carbonate or citrate are the preferred supplementation forms [71, 72].
- **Dosing Recommendations**: the general recommendation lies around 1000–1200 mg/day for adults; vegan athletes may require higher amounts to account for increased bone turnover [75]. Splitting total daily calcium into multiple smaller doses can improve bioavailability and reduce gastrointestinal discomfort [73]. It is recommended to consume calcium together with Vitamin D for enhanced absorption [74].
- **Impact on Health and Performance**: Adequate calcium status reduces fracture risk and maintains bone density in populations prone to deficiency [73]. Proper calcium intake supports recovery, prevents overuse injuries, and aids in overall musculoskeletal integrity [72].

Iron

Iron is essential for oxygen transport, energy production, and immune function. In sports performance, adequate iron levels underpin hemoglobin, myoglobin, and key mitochondrial enzymes [76, 77]. For vegan athletes, iron deficiency risk is elevated due to reliance on non-heme plant-based iron—less bioavailable than heme iron from animal sources. This limited absorption is further influenced by inhibitors like phytates and polyphenols, although vitamin C and organic acids enhance non-heme iron uptake [78, 79]. While vegans often show lower iron stores, their hemoglobin levels are generally comparable to omnivores [76].

Deficiency manifests in three stages—depleted iron stores, impaired erythropoiesis, and iron-deficiency anemia—leading to reduced oxygen transport capacity, mitochondrial dysfunction and fatigue [77, 79].

Non-anemic iron deficiency can also negatively impact VO_2 max and overall athletic output. Early intervention, especially when ferritin is below 20 µg/L, significantly improves aerobic capacity [80].

Key Considerations for Iron Supplementation

- **Dietary Sources and Bioavailability**: Non-heme iron in legumes, whole grains, leafy greens, and nuts has lower bioavailability. Vitamin C boosts absorption, whereas phytates and polyphenols hinder it. Intense training elevates hepcidin, reducing iron absorption. Administer iron when hepcidin levels are lower, typically before or well after exercise [78–80].
- **Dosing Recommendations**: Ferrous sulfate, ferrous gluconate, or ferrous fumarate at 30–100 mg of elemental iron per day [78]. Adjust dose based on ferritin levels, training intensity, and dietary inhibitors [77]. Ferritin (storage) and hemoglobin (oxygen transport capacity) blood levels should be used as marker for personalized supplementation strategies [80]. Consuming iron-rich foods or supplements together with Vitamin C (and other organic acids) effectively enhances bioavailability.
- **Impact on Health and Performance:** Maintaining proper iron levels is crucial for energetic metabolism and oxygen transport. Improving iron levels when a deficiency is at place, significantly improved aerobic capacity, a feature critical for high-resistance and explosive athletes.

Iodine

Iodine is essential for synthesizing the thyroid hormones triiodothyronine (T3) and thyroxine (T4), which regulate metabolism, neurological development, and thyroid function. Because vegan diets exclude typical animal-based iodine sources (e.g., fish, dairy, eggs), vegans face a higher risk of deficiency [81, 82]. Although seaweeds (e.g., kombu), iodized salt, and fortified foods can provide iodine, their availability and consistency vary widely [83]. Low iodine intake may lead to hypothyroidism, goiter, and metabolic disturbances—factors that can negatively affect athletic performance by reducing metabolic efficiency, thermoregulation, and muscle recovery [84].

Recent research confirms that vegans tend to have the lowest urinary iodine concentrations relative to omnivores, often below the WHO's optimal range of 100–200 µg/L [81, 82]. Iodine supplementation, usually 150 µg/day as potassium iodide, is a key preventive measure [81]. Food fortification—such as iodine-enriched plant milks or breads—can also help, although its impact depends on local regulations and availability [84]. Seaweed, while potentially high in iodine, can present toxicity risks due to highly variable content, underscoring the need for moderated intake [83].

Key Considerations for Iodine Supplementation

- **Dietary Sources and Variability:** Iodized salt, enriched plant milks, and fortified breads can provide consistent iodine, particularly in areas lacking mandatory iodization [81, 84]. Some algae like kombu can contain excessive iodine, posing toxicity risks if consumed frequently and in large amounts, algal supplementation should therefore be conducted with caution [83].
- **Dosing Recommendations:** WHO advises 150 µg/day for adults, 250 µg/day for pregnant/lactating women [85]. 150 µg/day of potassium iodide is typically considered safe and effective for preventing deficiency in vegans [81].
- **Impact on Health and Performance:** Adequate iodine is critical for synthesizing T3/T4 hormones, which drive metabolic rate, thermoregulation, and energy utilization—factors essential for athletic performance [84]. Proper iodine levels are required for effective metabolism as well as muscular and neurological health [86].

Vitamin K2

Vitamin K2 (menaquinone) is a fat-soluble micronutrient crucial for bone health, cardiovascular function, and inflammatory and metabolic processes. In vegan diets, natural sources of K2 (e.g., egg yolks, cheese, natto) are limited, making deficiency a concern [87]. Menaquinone-7 (MK-7), a more bioavailable form, can be sustainably produced through bacterial fermentation and is therefore suitable for vegan supplementation [88]. Vitamin K2 supports the carboxylation of vitamin K-dependent proteins such as osteocalcin and matrix Gla protein (MGP), which are essential for bone mineralization and preventing vascular calcification [89].

Recent studies highlight potential ergogenic effects of K2 through reducing exercise-induced inflammation and enhancing muscle recovery [90, 91]. MK-7 supplementation at 90–200 µg/day is considered safe and effective for improving K2 status, especially when combined with vitamin D and calcium for optimal bone health [87, 89]. Additionally, research suggests K2 may have metabolic benefits, as observed in individuals with polycystic ovary syndrome and hemodialysis patients [88, 92]. For vegan athletes, ensuring adequate vitamin K2 intake can mitigate risks associated with bone density loss and inflammation, thereby supporting overall performance and recovery.

Key Considerations for Vitamin K2 Supplementation

- **Dietary Sources and Bioavailability:** Traditional K2 sources (e.g., egg yolk, cheese) are off-limits in a vegan diet. Natto (fermented soy) contains high amounts of MK-7 but may not be widely consumed, mostly due to organoleptic reasons. MK-7 supplements produced via fermentation provide a vegan-compatible source of vitamin K2 [90].
- **Dosage Recommendations:** 90–200 µg/day of MK-7 is generally recognized as both safe and sufficient to enhance K2 status [87]. Co-supplementation of K2 with vitamin D and calcium further supports bone mineralization and skeletal integrity [89].
- **Impact on Health and Performance:** Adequate K2 status helps reduce fracture risk, improve bone density, and prevent arterial calcification [89]. Studies indicate that vitamin K2 can aid post-exercise muscle repair and reduce inflammatory markers, which is especially relevant for vegan athletes [90].

Selenium

Selenium is an essential trace element involved in antioxidant defense, muscle performance, and thyroid hormone regulation. It is incorporated into selenoproteins—such as glutathione peroxidase—that protect against oxidative stress and help maintain metabolic homeostasis [93, 94]. In vegan diets, selenium intake can be suboptimal because plant-based selenium content depends heavily on soil composition, highlighting the need for supplementation or fortified foods in this population [95–97].

Adequate selenium status benefits muscle recovery by limiting exercise-induced oxidative damage and supports thyroid function via the conversion of thyroxine (T4) to the more active triiodothyronine (T3) [98, 99]. In vegan athletes, selenium supplementation helps maintain optimal thyroid hormone levels and metabolic parameters. Recent findings also suggest selenium may combat sarcopenia by enhancing protein synthesis in muscle and preserving functionality in aging and athletic populations [94, 96]. Sodium selenate or selenium-enriched yeast are considered safe, effective vegan-friendly supplement forms. Co-supplementation of selenium with other antioxidants, like vitamin E and zinc, may amplify protective effects [98].

Key Considerations for Selenium Supplementation

- **Dietary Sources and Bioavailability:** Selenium content in grains, legumes, and nuts (e.g., Brazil nuts) depends on soil selenium levels, making intake inconsistent for vegans [95]. Cereals and breads enriched with selenium offer a potentially sustainable approach to enhance intake [96]. Sodium selenate or selenium-enriched yeast are well-absorbed and commonly recommended [93].
- **Dosing Recommendations:** An intake of 55 µg/day of elemental selenium for adults is recommended, though athletes may need more. Combining with Vitamin E and Zinc enhances benefits associated with muscle recovery and immune function [98].
- **Impact on Health and Performance:** Selenoproteins such as glutathione peroxidase mitigate the reactive oxygen species produced during high-intensity exercise [99]. Adequate selenium supports T4-to-T3 conversion, crucial for metabolic rate, MPS and energy utilization [96, 98]. It also impacts recovery and immune function [98].

Probiotics

Probiotics are live microorganisms that confer significant health benefits to the host. In sports nutrition, they have gained attention for their ability to modulate the gut microbiota, enhance nutrient absorption, and optimize physical performance. Vegan athletes may particularly benefit from probiotic supplementation to improve intestinal health and address challenges related to the bioavailability of essential nutrients [100, 101].

A fiber-rich vegan diet often promotes beneficial bacteria such as *Bifidobacterium* and *Lactobacillus*. However, these benefits can be substantially enhances with supplementation [102]. Specific strains like *Lactiplantibacillus plantarum* TWK10 have demonstrated improved amino acid bioavailability, improved muscle regeneration, and reduced inflammation post-exercise [101, 103]. Additionally, probiotics can positively influence the gut–microbiota–brain axis, potentially improving cognitive functions crucial in high-level sports [103].

Key Considerations for Probiotic Supplementation

- **Strain Selection:** Research supports the efficacy of strains like *Lactobacillus rhamnosus*, *Bifidobacterium breve*, and *Lactiplantibacillus plantarum* for enhanced nutrient absorption, immune function, and muscle recovery [101]. Different strains may yield distinct metabolic outcomes, necessitating careful selection based on performance goals [102].
- **Dosing Recommendations:** At least 1 × 10 [9] CFU/day for several weeks is generally recommended to achieve measurable clinical benefits. Combining probiotics with prebiotic fibers (e.g., inulin, fructooligosaccharides) fosters the growth of beneficial microbes and optimizes gut microbiota balance [100, 101].
- **Impact on Health and Performance:** Probiotics can mitigate exercise-induced inflammation, aiding in faster muscle recovery and reduced soreness. By influencing the gut–brain axis, probiotic supplementation may also boost concentration, decision-making, and mental resilience in competitive settings. Probiotics can also help in improving the bioavailability of certain essential nutrients, like amino acids and others derived from the metabolism of probiotic bacteria themselves [100–103].

Nitrates

Dietary nitrates have emerged as a key ergogenic aid for enhancing athletic performance. They are converted into nitrites (NO_2^-) and subsequently into nitric oxide (NO) via a nitric oxide synthase–independent pathway, increasing vasodilation, metabolic efficiency, and oxygen transport [104, 105]. These benefits translate into enhanced blood flow to working muscles and more efficient mitochondrial function, both of which are crucial in endurance sports and high-intensity intermittent activities [104, 106]. The effect appears most pronounced in athletes with lower baseline aerobic capacity, suggesting that vegans unaccustomed to dietary nitrates may benefit significantly from additional supplementation [107].

Beetroot juice is a common nitrate supplement, shown to reduce the oxygen cost of submaximal exercise and increase time to exhaustion [104, 108]. Benefits extend to rapid, explosive contractions by improving fast-twitch muscle function and recovery [107]. Typical doses range from 300–600 mg of nitrates daily, ingested about 2–3 h pre-exercise to maximize plasma nitrite levels (Jones, 2014; Murphy et al., 2022). Oral bacteria are essential for converting nitrates to nitrites, so excessive use of antiseptic mouthwash can inhibit this process and diminish ergogenic effects (González-Soltero et al., 2020).

Key Considerations for Nitrate Supplementation

- **Dietary Sources and Bioavailability:** Beetroot, spinach, and Swiss chard are rich in nitrates, aligning naturally with plant-based diets [107]. Other supplements associated with nitric oxide metabolism like L-Arginine and Citrulline have few evidence for their use and therefore are not recommended [108]. Beetroot juice and powder allow for more precise dosing, ensuring adequate nitrate intake [105].
- **Dosing Recommendations:** 300–600 mg of nitrates per day is commonly used in research, taken 2–3 h before exercise to elevate plasma nitrite levels [104]. Athletes with lower aerobic capacity or limited prior nitrate exposure may see more pronounced performance gains [107].
- **Impact on Health and Performance:** Improved blood flow and oxygenation to working muscles [108]. Enhanced utilization of energy substrates leads to increased exercise tolerance and performance [106].

Electrolytes

Electrolytes, including Na^+, K^+, Mg^{2+}, and Cl^-, are vital for fluid balance, neuromuscular function, and pH regulation. In sports contexts, maintaining adequate electrolyte levels is crucial to prevent performance declines, cramps, fatigue, and associated health risks. Vegan athletes may face limited dietary sources [109, 110]. Electrolyte supplementation strategies should be based on training intensity, body composition, sweat rate, and environmental conditions [109]. In the context of prolonged and intense exercise, keeping correct hydration levels is crucial for sports performance and electrolytes play a key role in keeping that equilibrium.

- **Sodium:** Key for preserving plasma volume and avoiding hyponatremia in prolonged activities. Sufficient sodium intake promotes fluid retention, reduces fatigue, and mitigates heat-related injuries [111]. Exercise-induced hyponatremia—low blood sodium—can cause confusion, weakness, and in severe cases, cerebral edema [109]. 300–600 mg of sodium per hour during prolonged exercise to maintain fluid balance and energy output [111]. Sodium-enriched rehydration solutions combined with carbohydrates enhance both fluid absorption and glycogen replenishment [112].
- **Potassium:** Works in tandem with sodium for osmotic balance and neuromuscular signaling. Deficiencies—though less frequent than sodium shortages—can impair muscle contractions and heart function, particularly under high-intensity training [112]. Daily recommended intake for adults is of 3500–4000 mg per day, athletes could probably benefit of a higher intake of 4700 mg per day [113, 114].
- **Magnesium:** Involved in over 300 enzymatic reactions, including ATP energy metabolism. Low magnesium disrupts muscle contraction, hinders recovery, and undermines energy production [110]. Recommended intake is of 300–600 mg per hour during extensive exercise with hydrating solutions containing carbohydrates [112].

Taurine

Taurine is a non-essential sulfur-containing amino acid predominantly found in animal tissues. Its antioxidants, anti-inflammatory, and ergogenic properties have been widely studied, making it particularly relevant for vegan athletes who may lack significant dietary sources of taurine. Supplementation has demonstrated improvements in both aerobic and anaerobic performance by enhancing oxygen utilization, optimizing intracellular calcium levels, and reducing oxidative stress [115, 116].

Research indicates that acute doses of 1–6 g of taurine before exercise can increase endurance, power output, and overall muscular performance [117, 118]. Additionally, taurine's antioxidant role helps mitigate exercise-induced damage and accelerate muscle recovery [116]. Its metabolic benefits—such as improved insulin sensitivity and lipid metabolism—are also noted, particularly in populations with insulin resistance [119].

Key Considerations for Taurine Supplementation

- **Dosage Recommendations**: 1–6 g/day, often divided based on training intensity and performance goals [115]. For immediate ergogenic effects, 2–3 g taken 1–2 h before exercise is recommended. Chronic use alongside regular training may maximize long-term benefits [117, 118]. Vegan athletes, lacking direct dietary taurine sources, can particularly benefit from supplementation for both performance and metabolic support [115].
- **Mechanism of Action**: Taurine reduces oxidative damage by neutralizing reactive oxygen species (ROS), aiding muscle protection and recovery [116]. By optimizing intracellular calcium, taurine enhances muscle contraction and delays fatigue [118].
- **Impact on Health and Performance**: Studies show increased endurance capacity, lowered lactate levels, and better power output in various sports [117, 118]. Improved recovery from high-intensity exercise, with reductions in markers of muscle damage [116]. Taurine supplementation may boost insulin sensitivity and help regulate body weight, potentially advantageous in athletes seeking refined body composition [119].

Vitamin A

Vitamin A (retinol) is a fat-soluble micronutrient crucial for vision, immune function, cellular growth, and bone metabolism. In vegan diets, vitamin A intake relies predominantly on the conversion of carotenoids (e.g., beta-carotene) into active retinol—a process influenced by genetic, metabolic, and dietary factors [120, 121]. Retinol is integral in forming rhodopsin for low-light vision, regulating epithelial tissue differentiation, and aiding collagen synthesis—key to wound healing and post-exercise recovery [122].

For athletes, adequate vitamin A supports immune function, reduces oxidative stress, and enhances muscle recovery following high-intensity workouts [123, 124]. However, relying solely on carotenoid conversion, which can be affected by genetic variants in enzymes like beta-carotene-15,15'-dioxygenase could be insufficient [124]. Retinol also plays a role in calcium metabolism and bone formation, helping to prevent injuries in impact sports. Additionally, its influence on vision can benefit sports requiring precise hand–eye coordination [120, 122].

Key Considerations for Vitamin A Supplementation

- **Dietary Sources and Bioavailability:** While carotenoids are abundant in fruits and vegetables, absorption and conversion to retinol can be limited. Liposomal vitamin A shows superior bioavailability [120]. Polymorphisms in key enzymes can lead to reduced beta-carotene conversion, making supplementation particularly important for some vegans [124].
- **Dosing Recommendations:** 700–900 µg retinol equivalent per day, though individual needs may vary, especially for active vegans [125]. Consuming healthy fats alongside carotenoid-rich foods enhances vitamin A absorption and conversion [125]. Deficiency can impair performance, excessive retinol intake leads to hypervitaminosis A. Balancing intake with other fat-soluble vitamins (D, E, K) is essential.
- **Impact on Health and Performance:** Retinol helps mitigate oxidative damage from intense exercise, accelerating muscular recovery [123]. Adequate vitamin A supports epithelial integrity, immune response, and bone metabolism—vital for resilience against injury and infection [122].

Magnesium

Magnesium is an essential mineral involved in over 300 enzymatic reactions, including ATP production, protein synthesis, and neuromuscular function. While vegan diets often include magnesium-rich foods (e.g., nuts, seeds, legumes, whole grains), intense exercise may increase magnesium requirements, making supplementation beneficial [126, 127]. Adequate magnesium supports muscle contraction and relaxation, helps prevent cramps and fatigue, and enhances exercise performance [128, 129]. Reviews indicate that daily doses of 300–450 mg of magnesium can boost strength, aid recovery, and reduce exercise-induced damage [127]. The mineral also offers antioxidant properties, mitigating stress and accelerating muscle repair, which is especially valuable to vegan athletes with high nutrient demands [130].

Key Considerations for Magnesium Supplementation

- **Dietary Sources and Bioavailability:** Nuts, seeds, legumes, whole grains, spinach, pumpkin seeds, black beans and others present effective magnesium dietary sources. Nevertheless, vegan athletes should balance supplemental and dietary magnesium to avoid deficiencies [126]. Citrate and malate salts of magnesium are preferred due to higher absorption rates compared to inorganic forms like magnesium oxide [131].
- **Dosage Recommendations:** 300–450 mg per day is commonly recommended for athletes, although medical advice may warrant specific adjustments [127]. Pairing magnesium with zinc or potassium may enhance metabolic and muscular gains. Even with supplementation, vegan athletes benefit from a base of nutrient-dense, magnesium-rich plant foods [126].
- **Impact on Health and Performance**: Adequate magnesium regulates calcium, sodium, and potassium flux, supporting optimal contraction and relaxation [128, 129]. Magnesium helps reduce exercise-induced oxidative stress, diminishing DOMS and speeding recovery [130]. As exposed in the above section about electrolytes, magnesium can also be a key nutrient associated with proper hydric equilibrium, helping maintain proper hydration in extensive and prolonged exercise.

Summary and Discussion

This review underscores the increasing relevance of vegan-friendly supplements in bridging nutritional gaps and optimizing sports performance for vegan athletes. Despite the rising adoption of vegan diets due to ethical, environmental, and health motivations, this dietary choice poses unique challenges, particularly for athletes with elevated nutritional needs. A summary of the reviewed supplements and their associated effects, recommendations and preferred sources are presented in Fig. 1. These 19 supplements are supported by research to be critical for sports performance, providing potentially game-changing effects in vegan athletes, especially in the case where formal deficiencies are usually present (e.g.: iron, B12, K2…).

We can highlight our findings for vegan supplementation focused on sports performances as follows.

- **Protein Powders:** Vegan protein powders, when well-formulated, offer comparable benefits to whey and casein in muscle protein synthesis and recovery. Combining multiple plant protein sources enhances the amino acid profile, addressing concerns over bioavailability. A good protein powder should be of over 70% protein purity, and have over 3 g of Leucine, 1 g of Isoleucine and 1 g of valine per serving. Mixtures of plant-protein isolates from pea, mung bean or soy, and/or fortified products tend to be the best choice.
- **Creatine:** Vegans, who typically have lower baseline creatine levels, show pronounced benefits from supplementation. Synthetic creatine monohydrate, a widely accepted vegan option, significantly boosts strength, power, and cognitive function.
- **Beta-Alanine:** Supplementation effectively enhances muscle carnosine concentrations in vegans, supporting fatigue resistance and recovery. Dividing doses minimizes side effects like paresthesia.
- **Caffeine:** As a universal ergogenic aid, caffeine benefits both vegan and omnivorous athletes. Personalized dosage strategies are essential to balance performance gains against potential adverse effects such as disrupted sleep.
- **Calcium, Vitamin K2, Vitamin D:** These supplements have proven to be extremely effective for maintaining musculoskeletal health and function. As vegan athletes are statistically at higher risk of injury, considering a supplementation strategy with these nutrients is key for preventing fractures and improving recovery.
- **Omega-3 Fatty Acids:** Plant-based omega-3 sources (e.g., algae-derived DHA) offer viable alternatives to fish oil, though their efficacy in EPA conversion warrants further investigation. Targeted dosing supports cardiovascular and cognitive health.
- **Probiotics:** Have been demonstrated to positively influence the gut-microbiota-brain axis, supporting metabolic, neurologic and gut health. They have also been demonstrated to improve amino acid bioavailability and muscle regeneration, and to reduce inflammation post-exercise.
- **Selenium, Zinc and Iodine:** These nutrients have been shown to act synergistically in supporting adequate endocrine function and metabolism. Proper levels of these nutrients are critical for muscular health and neurological function.
- **Vitamin B12:** Cobalamin is crucial for red blood cell formation, DNA synthesis, and neuronal function. Vegan diets lack direct sources of B12, making supplementation essential to prevent deficiencies leading to anemia, cognitive issues, and cardiovascular risks. Fortified foods and supplements (e.g., cyanocobalamin or methylcobalamin) are effective. For athletic performance, B12 ensures proper hemoglobin synthesis, crucial for oxygen transport and recovery.
- **Iron:** Supports oxygen transport and energy production, essential for athletic performance. Vegan diets rely on non-heme iron, which has lower bioavailability than heme iron. Absorption can be enhanced by pairing iron-rich foods with vitamin C. Recommended supplementation includes ferrous salts.
- **Nitrates:** Dietary nitrates, primarily from beetroot, convert to nitric oxide, enhancing blood flow, oxygen delivery, and metabolic efficiency. Benefits are pronounced in endurance and high-intensity activities. Beetroot juice and powders are the most recommended sources, other supplements like L-Arginine and Citrulline still require more research. Avoiding excessive use of antiseptic mouthwash is essential to maintain nitrate-nitrite conversion
- **Electrolytes:** Electrolytes like sodium, potassium, and magnesium are vital for hydration, muscle function, and pH regulation. For athletes, replenishment through supplements or enriched hydration solutions is recommended, especially in intense or prolonged exercise.
- **Taurine:** Taurine, absent from vegan diets, supports muscle contraction, oxygen utilization, and oxidative stress reduction. Acute doses of 1–6 g/day improve endurance and recovery, especially in high-intensity sports. Chronic supplementation enhances long-term metabolic and muscular benefits.
- **Vitamin A:** Retinol is essential for vision, immunity, and recovery. Vegan diets depend on carotenoid conversion, which can be inefficient. Liposomal vitamin A supplementation (700–900 µg/day) ensures sufficiency. It supports post-exercise recovery, bone health, and performance in sports requiring coordination.
- **Magnesium:** Magnesium is involved in energy metabolism, muscle function, and neuromuscular balance. Vegan diets provide dietary magnesium, but intense exercise increases needs. Magnesium citrate or malate is recommended for superior absorption, and pairing with sodium, potassium and/or zinc enhances benefits.

While not all of the mentioned nutrients are truly "essential" in the common sense used in the field, the authors do recognize that they should be considered as essential in the context of high-performance vegan athletes where nutritional gaps stemming from their diet could play decisive differences in competition and sports performance. Combining supplements with nutrient-dense plant-based food enhances bioavailability and having a carefully tailored and personalized diet should always be considered priority for high-performance athletes.

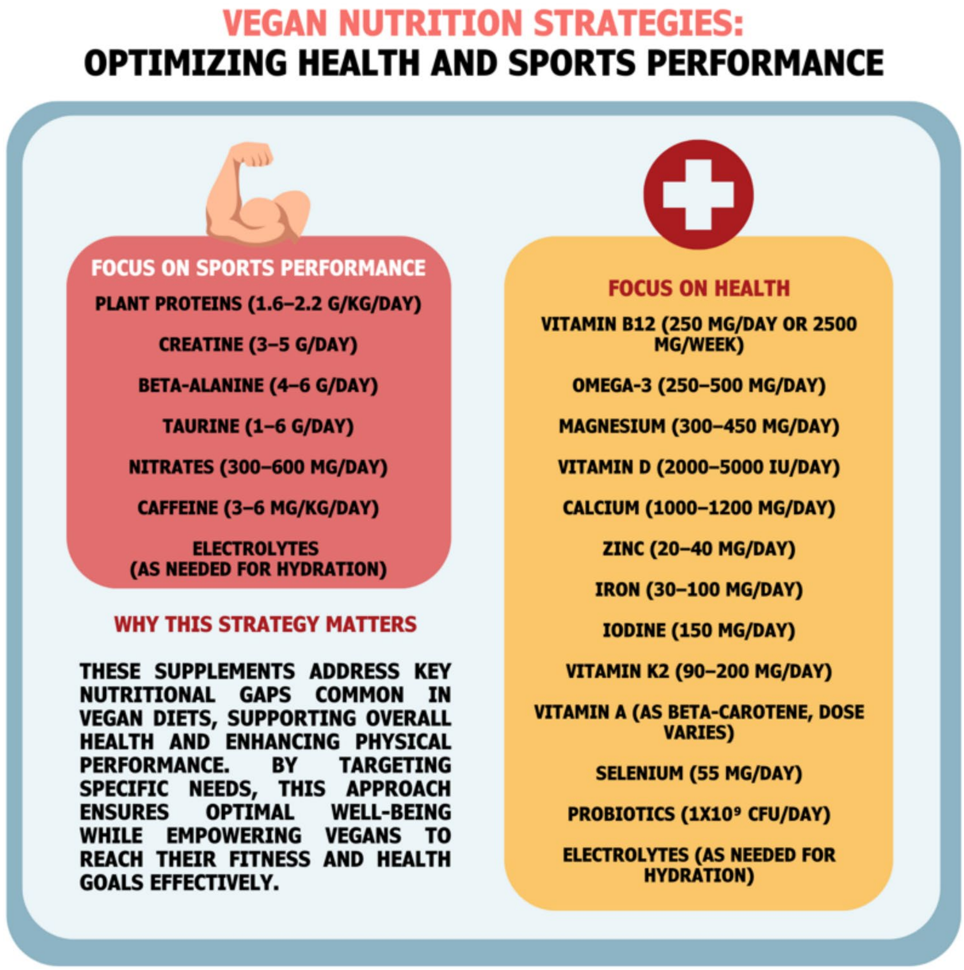

Fig. 1 Infographic summary of the recommended supplements and their effect. Please note that all the supplements under "Focus on health" are still critical for metabolism and sports performance, but not all "Focus on sports performance" supplements are critical for general health (although many of them could be beneficial in most cases). Please also note that the following supplements are considered essential for most (if not all) vegan diets seeking to optimize health, regardless of sports activity level: Vitamin B12, Vitamin D, Omega-3, Iron, Calcium, Zinc, Iodine, Selenium, Vitamin K2, Magnesium

Additionally, strategizing nutrition related to timing (such as post-workout protein intake and pre-exercise nitrate or caffeine use) and synergistic effects (such as the coupled consumption of Calcium, Vitamin D and Vitamin K2 for enhancing bioavailability) optimize ergogenic effects and metabolic benefits, greatly improving the gains from utilizing nutritional supplements alone.

The authors also have to emphasize the fact that there is no such thing as a "fit-for-all" nutritional strategy. This means that the ideal scenario for each athlete (and any patient in that case) should be to perform the necessary biochemical assays in order to assess the urgency to supplement each nutrient and the amount to supplement with. While this review has been extensive on the proper protocols and benefits associated with each nutrient, there are still knowledge gaps in the area. These knowledge gaps that are prevalent in general nutrition and sports sciences are only highlighted in the case of vegan populations, whose demographics have been traditionally underrepresented (even though in the last 10 + years significant efforts have been made on that front).

These research gaps are mostly associated with: (a) synergetic effects of different supplements (where due to the enormous research space available seems impractical to completely fill); (b) the bioavailability of plant-based nutrients in whole foods and how to improve it in simple fashion (as not every vegan athlete is able to afford specialized supplementation); (c) sex-specific needs in vegan athletes (when combining both vegan and female population the underrepresentation problems in research are further highlighted, posing serious impairments on specialized nutritional strategizing in female vegan athletes). Bridging these research gaps with randomized control studies and specialized research is crucial for further safe development of vegan nutrition science.

Conclusions

This narrative review has given detailed guidelines and provided extensive research for 19 key supplements considered to be crucial in leveling the high-performance competition field for vegan athletes. The discussion included: protein powders, creatine, beta-alanine, caffeine, vitamin B12, vitamin D, omega-3 fatty acids, zinc, calcium, iron, iodine, vitamin K2, selenium, probiotics, nitrates, electrolytes (including sodium and potassium), taurine, vitamin A, and magnesium.

While probably most of the vegan athlete population would benefit from taking these supplements, careful consideration into timing, synergetic effects and sourcing, as well as individual blood-serum levels, should be considered prior to implementation.

Further research is needed in order to optimize nutritional intake from whole foods. Sex-specific needs for vegan athletes are also severely underrepresented and therefore require further extensive research. Finally, more biochemical and metabolic research associated with potential synergetic effects between nutrients is needed in order to maximize benefits from supplementation.

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  - o This review highlights the differences between several types of diets compared to vegan diets and also provides extensive perspectives on the incorporation of the main 3 macronutrients (proteins, fats and carbs), with a focus on athletic related goals, as well as providing interesting insights on the most common nutritional deficiencies and their likelihood.
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  - o This randomized controlled trial compares omnivorous and vegan diets in the context of resistance/strength training, giving substantial evidence on the effectivity of vegan-protein based diets for myofibrillar protein synthesis and skeletal muscle hypertrophy in young adults, where both processes are recognized as cornerstones for athletic performance in most competitive sports.
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  - o In this randomized clinical trial involving several pairs of healthy identical twins, omnivorous and vegan diets are compared. Participants following a healthy vegan diet experienced significantly lower low-density lipoprotein cholesterol, improved fasting insulin levels, and greater weight loss than their counterparts consuming a healthy omnivorous diet. This study gives substantial evidence on the cardiovascular positive effects of plant-based diets, which can signify an important effect also on athletes following vegan diets.

Author Contributions A.A.V.N was the main researcher and leader of this investigation, being involved in all stages of research. He did the primary literature revision and writing, and crafted all figures and tables. A.H.D is the main corresponding authors and was involved in all stages of research, he was the main responsible of final translating, writing, editing and revisiting of the manuscript. M.H.M was involved in all stages of research, with focus on final editing and research supervision.

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Declarations

Competing Interest The authors declare no competing interests.

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