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Plant-Based Diets in Professional Athletes: Impact on Inflammatory Biomarkers, Gut Microbiome Diversity, and Muscle Protein Synthesis - A Systematic Review

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Abstract

Background: Plant-based dietary patterns are increasingly adopted in high-performance sport, yet their effects on inflammation, the gut microbiome, and skeletal-muscle anabolism remain incompletely integrated.

Objectives: To synthesize the complete uploaded evidence corpus concerning inflammatory and oxidative biomarkers, microbial diversity and metabolites, muscle protein synthesis (MPS), hypertrophy, recovery, and performance in professional or highly trained athletes.

Material and methods: Systematic and narrative review of peer-reviewed randomized controlled clinical trials (RCTs), acute crossover metabolic isotope tracer studies, meta-analyses and systematic reviews, observational cross-sectional studies in competitive and recreational athletes, 16S rRNA/metagenomic gut microbiome profiles, and metabolomic analyses of short-chain fatty acids (SCFAs) and oxidative stress biomarkers.

Results: Plant-forward patterns were associated with lower C-reactive protein (CRP) and, in footballers, lower urinary F2-isoprostane with greater plant-food adherence; evidence for interleukin-6, tumor necrosis factor- α , and other cytokines was sparse or inconsistent. Fiber- and lentil-protein-rich exposures increased short-chain-fatty-acid (SCFA)-producing taxa and fecal acetate/butyrate in small training studies, whereas athlete microbiome interventions overall were heterogeneous and did not establish a reproducible ergogenic signature. Unfortified single-source plant proteins often produced lower aminoacidemia or acute MPS than whey, but complementary blends, adequate doses, and leucine fortification generally eliminated this difference. Longer resistance-training trials reported similar gains in lean mass and strength when total protein and training were sufficient. Direct evidence in professional athletes, women, and fully vegan cohorts remained limited.

Conclusion: A well-planned plant-based diet can support elite training and recovery, but benefits are conditional on adequate energy, carbohydrate, protein quantity and distribution, complementary amino-acid profiles, and correction of micronutrient deficiencies. Anti-inflammatory and microbiome effects are plausible and partly supported; claims of superior performance are not established.

Keywords: Athletes; Plant-based diet; Inflammation; C-reactive protein; Gut microbiota; Short-chain fatty acids; Muscle protein synthesis.

1. Introduction

Plant-based nutrition spans heterogeneous exposures, from plant-forward omnivorous patterns to vegetarian and fully vegan diets. This distinction is material in sport: a minimally processed, fiber- rich pattern dominated by legumes, whole grains, fruit, vegetables, nuts, and seeds is metabolically different from an energy-matched pattern dominated by refined starches, sugars, and ultra-processed meat analogues. Reviews of athletic populations generally indicate no inherent decrement in aerobic, anaerobic, or strength performance when energy and nutrient needs are met, but they do not demonstrate that plant-based diets are uniformly ergogenic [4,5,25,26]. A 2025 systematic review reported mixed performance findings across 30 studies, illustrating both the expanding literature and the limitations created by variable definitions, athlete levels, and dietary implementation [28]. Evidence specific to female athletes likewise indicates broadly comparable outcomes under nutritionally adequate conditions, while emphasizing low energy availability, menstrual and endocrine health, iron status, and relative energy deficiency in sport as implementation-sensitive concerns rather than inevitable consequences of vegetarianism [29].

Three interacting physiological domains provide the rationale for the present synthesis. First, strenuous training generates reactive oxygen and nitrogen species and transient inflammatory signaling required for remodeling. Plant foods supply polyphenols, carotenoids, vitamins, unsaturated lipids, nitrate, and fermentable substrates that may reduce chronic inflammatory tone and oxidative damage; however, indiscriminate suppression of exercise-induced redox signaling may attenuate adaptation [2,30,31]. Second, dietary fiber and other microbiota-accessible carbohydrates are fermented to acetate, propionate, and butyrate. These metabolites can support epithelial integrity, immunoregulation, insulin sensitivity, and substrate handling, although most proposed ergogenic pathways remain mechanistic rather than proven in athletes [9,38]. Third, plant proteins frequently have lower digestibility and lower proportions of leucine, lysine, methionine, or total essential amino acids (EAAs) than animal proteins. Acute anabolic responses may therefore differ at equal protein doses, but processing, blending, fortification, dose, meal distribution, and resistance exercise can materially alter the comparison [21,32,33].

The objective was to evaluate whether plant-based diets in professional and highly trained athletes influence (i) systemic inflammation and oxidative stress, (ii) gut microbial diversity, composition, barrier-related function, and SCFA production, (iii) MPS and hypertrophic adaptation, and (iv) recovery and performance. A secondary objective was to translate the

evidence into operational recommendations while separating direct athlete evidence from extrapolation.

2. Materials and Methods

This article was prepared as a source-bounded systematic review with narrative synthesis of the scientific literature on plant-based diets in professional and highly trained athletes, with particular emphasis on inflammatory and oxidative biomarkers, gut-microbiome diversity and metabolic function, muscle protein synthesis (MPS), hypertrophic adaptation, recovery, and athletic performance. The synthesis drew on all 39 peer-reviewed documents supplied with the project, comprising athlete-specific observational studies and randomized or controlled interventions, stable-isotope tracer studies, resistance-training trials, systematic reviews and meta-analyses, and mechanistic, narrative, and critical reviews. The evidence set was fixed a priori and consisted of files named 1.pdf through 39.pdf. Every file was screened in full and retained, and citation numbers were preserved according to the corresponding filename. Because the corpus was supplied rather than retrieved through an independently reproducible database search, the review was organized according to PRISMA principles of transparent identification, eligibility assessment, extraction, and synthesis, but should not be interpreted as an exhaustive search of the global literature.

Consistent with the approach used in comparable sports-nutrition reviews, priority was given to randomized controlled trials, athlete-specific investigations, systematic reviews, and meta-analyses reporting objective physiological or performance outcomes [11,18,19,23,26,31,36,37]. Evidence from professional football, soccer, and water-polo populations was considered most directly applicable [1,10,12,17]. Controlled studies in resistance-trained or physically active adults were included when they provided relevant information on amino-acid kinetics, MPS, lean mass, strength, recovery, or training adaptation [6,22,24,34]. General-population studies and mechanistic reviews were retained when they clarified inflammatory, redox, gastrointestinal, microbial, or anabolic pathways relevant to athletes.

The included literature was grouped thematically into four domains: (i) inflammatory and oxidative-

stress outcomes, including C-reactive protein, interleukins, tumor necrosis factor- α , F2-isoprostanes, and oxidative DNA-damage markers; (ii) gut-microbiome composition and function, including alpha diversity, specific microbial taxa, short-chain fatty acids, microbial metabolic pathways, and intestinal-barrier integrity; (iii) MPS and hypertrophic adaptation,

including protein digestibility, essential-amino-acid and leucine availability, postprandial aminoacidemia, lean mass, muscle cross-sectional area, and strength; and (iv) integrated recovery, health, and performance outcomes. For each source, the population, training status, study design, dietary exposure, comparator, intervention duration, sample size, analytical method, principal quantitative findings, and stated limitations were extracted. Findings were synthesized narratively because substantial clinical and methodological heterogeneity precluded a valid new meta-analysis. Quantitative estimates were reported only when they had been provided by the uploaded primary studies or meta-analyses. Methodological quality was considered through study-design hierarchy, population directness, randomization and comparator quality, sample size, dietary control, intervention adherence, duration, validity of outcome measurement, statistical precision, and consistency with the wider evidence base. Greater interpretive weight was assigned to controlled athlete trials, stable-isotope measurements of MPS, validated biochemical assays, and longitudinal training outcomes than to cross-sectional associations or mechanistic inference. Because the included reviews employed different formal appraisal instruments and several narrative sources did not permit uniform item-level assessment, certainty was evaluated qualitatively rather than by applying a single retrospective scoring system. As only previously published, anonymized, or aggregated data were examined, ethical approval and informed consent were not required for this review.

Two methodological caveats apply throughout. First, direct evidence in professional athletes was limited, and much of the anabolic and dietary evidence was derived from healthy, active, or resistance-trained adults; extrapolation to elite competition, congested schedules, high training loads, and sport-specific gastrointestinal stress must therefore remain cautious. Second, definitions of plant-based, vegetarian, and vegan diets; protein sources and doses; training status; microbiome sequencing and bioinformatic methods; inflammatory biomarkers; and performance outcomes differed substantially among studies. These differences limited direct quantitative comparison and required most cross-study conclusions to remain qualitative rather than pooled.

3. Methods

3.1. Characteristics of the evidence base

The corpus contained athlete-specific observational and intervention studies, controlled feeding or supplementation studies in active adults, systematic reviews and meta-

analyses, and mechanistic or narrative reviews. Direct professional-athlete evidence included male footballers, elite football players, professional female soccer players, and elite male water-polo players [1,10,12,17]. The remaining experimental evidence was largely derived from healthy young or resistance-trained adults.

This distribution is consequential: professional sport entails high energy expenditure, congested schedules, travel, gastrointestinal stress, and periodized training that are not reproduced by most laboratory trials.

Domain	Most direct evidence	Integrated interpretation	Certainty
Inflammation/ oxidative stress	Footballer oxidative-marker study; CRP meta-analyses	Lower CRP and F2-isoprostane are plausible; cytokine evidence is inconsistent and largely non-athlete	Low–moderate
Gut microbiome	Training plus lentil protein; elite football, soccer, and water-polo studies	Diet and protein source can alter taxa and SCFA pathways, but no universal “athletic microbiome” or proven ergogenic effect exists	Low
MPS/hypertrophy	Stable-isotope blend trials; resistance-training RCTs	Leucine-fortified or complementary plant blends at adequate doses can match whey; single sources at equal lower doses may not	Moderate

Performance/ recovery	Athlete reviews and heterogeneous interventions	Performance is generally main- tained with adequate diet; supe- riority over omnivorous diets is unproven	Low
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Table 1: Principal outcome domains and overall interpretation of the supplied evidence.

3.2 Impact on inflammatory biomarkers and oxidative stress

The most direct oxidative-stress evidence was a matched study of 45 male footballers and 45 non-

athletes. Footballers had a higher overall plant-based diet index ($\beta = 9.8$, $p < 0.001$), and greater plant-food adherence was inversely associated with urinary F2-isoprostane, although the cross sectional design precluded causal attribution and the healthy and unhealthy plant-based subindices

did not differ between groups [1]. This distinction argues against treating all plant-derived foods as

physiologically interchangeable.

Across broader populations, the most consistent inflammatory signal concerned CRP. A metaanalysis of 30 observational and 10 intervention studies found vegetarian dietary patterns associated with lower CRP (weighted mean difference [WMD] -0.61 mg/L; 95% CI -0.91 to -0.32), fibrinogen (WMD -0.22 g/L; 95% CI -0.41 to -0.04), and leukocyte count, but intervention data were insufficient for pooling [15]. Another meta-analysis of 21 cross-sectional studies reported lower CRP in vegans (mean difference -0.54 mg/L; 95% CI -0.79 to -0.28 ; $p < 0.0001$) and a smaller association in vegetarians (-0.25 mg/L; 95% CI -0.49 to 0.00 ; $p = 0.05$), with no substantial pooled effects for the other assessed inflammatory markers [39]. In randomized trials, plant-based patterns reduced CRP by approximately 1.13 mg/L (95% CI -1.52 to -0.75) across seven trials, but heterogeneity was high and certainty low; exclusion of exercise co-interventions yielded an estimate of -0.94 mg/L (95% CI -1.43 to -0.46) [18].

A more recent diet-pattern meta-analysis reported a significant CRP reduction for vegetarian diets (ratio of means 0.82 ; 95% CI 0.69 – 0.98 ; $p = 0.0297$), whereas the vegan estimate was imprecise and not significant; effects on malondialdehyde, 8-hydroxy-2'-deoxyguanosine, and interleukin-6 were weak or nonsignificant [3]. A systematic review of observational and

intervention studies similarly found inverse associations between plant-forward patterns and oxidative or proinflammatory biomarkers, while rating most intervention evidence low-to-moderate quality [31]. Collectively, these results support a modest effect on basal CRP more strongly than a generalized suppression of IL-6, TNF- α , or exercise-induced inflammation. Mechanistically, lower saturated-fat exposure, higher unsaturated-fat and antioxidant intake, improved adiposity and glycemic control, endothelial effects, and microbiome-derived metabolites may contribute. Cardiovascular and endurance-oriented reviews propose improved blood viscosity, arterial flexibility, tissue perfusion, glycogen storage, and antioxidant capacity as potentially favorable properties [2]. These mechanisms are biologically coherent but cannot establish improved competitive performance. Moreover, exercise-generated oxidants participate in mitochondrial biogenesis and inflammatory resolution. Whole-food antioxidant matrices can be periodized around heavy competition or recovery blocks, whereas chronic high-dose isolated antioxidant supplementation may blunt redox-sensitive adaptation [30].

3.3 Gut microbiome diversity, metabolites, and barrier integrity

Athletic microbiomes are shaped by diet, training volume, body composition, geography, medication exposure, travel, and gastrointestinal symptoms. Metagenomic analysis of 418 public datasets found competitive-athlete status associated with taxonomic differences, enrichment of SCFA-producing organisms, and microbial biosynthetic potential for vitamin B12, aminoacid derivatives, and other metabolites; causality and the independent contribution of diet could not be resolved [14].

Reviews describe higher abundance of SCFA-related taxa and enhanced metabolic capacity in some endurance cohorts, yet extreme training accompanied by inadequate fueling may increase permeability, inflammation, and gastrointestinal disturbance [7,8]. A 2026 systematic review of 18 controlled interventions found changes in diversity and composition generally small and variable, SCFAs infrequently measured, and no consistent performance benefit linked to microbiome change [11]. Thus, taxonomic novelty should not be conflated with functional benefit.

The strongest plant-protein intervention signal arose from 24 adults undertaking 12 weeks of resistance training. Lentil-protein foods increased microbial diversity, enriched *Fusicatenibacter*, *Faecalibacterium*, and *Agathobacter*, and increased fecal acetate and butyrate relative to less pronounced changes with animal protein [6]. In 45 elite football players receiving 30 g/day of whey, pea, rice, or a plant blend for eight weeks, alpha diversity remained

stable, while source specific taxonomic and predicted functional shifts occurred: rice protein was associated with greater representation of succinate-to-butyrate pathways, whereas pea and the blend were associated with reductions in some fermentative taxa and greater predicted cadaverine-related potential [17]. The divergence between these trials demonstrates that “plant protein” is not a uniform microbiome exposure and that isolate composition, background fiber, dose, and habitual diet matter.

In 20 elite male water-polo players, vegan protein with added prebiotics and probiotics increased skeletal muscle mass, body cell mass, arm circumference, and protein mass while reducing fat mass; acetate- and propionate-related pathways correlated with increased skeletal muscle mass.

The uncontrolled contribution of the synbiotic components and small sample preclude attribution to plant protein alone [10]. Similarly, 200 mL/day of kefir for 28 days in 21 professional female soccer

players increased Shannon and Chao1 diversity and the abundance of *Akkermansia muciniphila* and *Faecalibacterium prausnitzii*; their abundance correlated with estimated VO2 max and finishing speed, but the fermented dairy exposure provides supportive microbiome evidence rather than direct evidence for a plant-based diet [12].

Plant-rich diets supply microbiota-accessible carbohydrates that support saccharolytic fermentation. Acetate can circulate as a substrate, propionate participates in hepatic and intestinal gluconeogenic signaling, and butyrate fuels colonocytes and supports epithelial tight-junction and immune functions.

G-protein-coupled receptor signaling and histone-deacetylase inhibition provide plausible links to insulin sensitivity, inflammation, and substrate use [9,38]. These pathways remain insufficiently validated during competition; fecal SCFA concentration reflects net production, absorption, and transit rather than production alone. General-population reviews report that vegan and vegetarian diets tend to enrich saccharolytic organisms and may produce more diverse and stable ecosystems, but findings for *Faecalibacterium*, *Coprococcus*, and *Enterobacteriaceae* are inconsistent [16,35]. Athlete-focused dietary reviews warn that high protein combined with low fiber, heavy use of simple carbohydrates, and unnecessary food avoidance may reduce microbial resilience; adequate fiber, varied protein sources, unsaturated fats, and selected pre-, pro-, or synbiotics are more defensible than taxon-targeted claims [13]. Protein reaching the colon may yield both SCFAs and potentially adverse metabolites such as ammonia, phenols, indoles, hydrogen sulfide, and biogenic amines. Consequently, the

microbiome objective should be adequate fermentable substrate and gastrointestinal tolerance rather than maximal protein supplementation.

3.4. Muscle protein synthesis and hypertrophic adaptation

3.4.1. Acute anabolic physiology

Post-exercise MPS is governed by EAA availability, leucine-triggered mechanistic target of rapamycin complex 1 signaling, protein digestion and absorption, splanchnic sequestration, muscle perfusion, training status, age, energy availability, and the exercise stimulus. Soy and wheat have historically produced lower acute MPS than whey, milk, beef, or egg at isonitrogenous doses, plausibly because of lower digestibility, EAA density, and leucine or limiting-amino-acid content [21,32]. Greater amino-acid oxidation after some plant proteins may further reduce substrate available for tissue synthesis [33].

The acute disadvantage is modifiable. In a randomized crossover trial, all supplements increased MPS above fasting values, but an unfortified pea–canola blend produced a smaller response than leucine-fortified blend and whey; MPS did not differ between the fortified blend and whey

($p = 0.052$) [24]. In resistance-trained adults ingesting 32 g after exercise, a pea–brown-rice–canola blend produced lower four-hour plasma EAA availability than whey (approximately 44% lower; $p = 0.04$), yet myofibrillar protein synthesis increased similarly over four hours with no condition interaction [34].

These findings show that aminoacidemia and MPS are related but not interchangeable endpoints and that a sufficiently dosed complementary blend can compensate for lower circulating EAA exposure. A systematic review of recovery studies concluded that single-source plant proteins often underperformed whey in acute settings, whereas blends supplying at least 30 g protein and approximately 2.5g leucine generally supported comparable MPS; evidence for soreness, muscle-damage biomarkers, and function was heterogeneous and at moderate-to-high risk of bias [23]. Practical strategies include increasing dose, blending legumes with cereal or seed proteins, adding the limiting EAA or leucine, and using isolates or concentrates when whole-food volume or fiber compromises peri-exercise tolerance [21,32,33].

3.4.2. Longitudinal hypertrophy, strength, and performance

Acute MPS differences do not necessarily predict long-term adaptation. A meta-analysis of 16 trials found no protein-source effect on absolute lean mass or strength, although animal protein modestly favored percentage lean mass and produced a 0.41-kg greater absolute lean-mass gain

(95% CI 0.08–0.74) in adults younger than 50 years [19]. A later meta-analysis of 43 randomized trials found a small advantage of animal protein for muscle mass in younger, but not older, adults; soy was equivalent to animal protein, and protein source did not consistently affect strength or physical performance [36]. A Bayesian meta-analysis found plant protein superior to no/low protein for overall athletic outcomes (standardized mean difference 0.281; 95% credible interval 0.159–0.412) but slightly inferior to other proteins (standardized mean difference –0.119; 95% credible interval –0.209 to –0.028), with small samples and moderate heterogeneity limiting confidence [37].

Recent training trials support equivalence under optimized conditions. Forty-four untrained young men consuming 45 g/day of soy–pea blend or whey during 12 weeks of supervised resistance training gained similar whole-body and regional lean mass, vastus lateralis cross-sectional area, and leg-press one-repetition maximum; all between-group comparisons were nonsignificant [22]. A systematic review of 13 studies likewise found plant isolates, predominantly soy, produced improvements in lean mass, muscle thickness, and strength similar to whey or leucine comparators during resistance training [20]. These results should not be overextended to poorly planned whole-food vegan diets, energy deficit, or professional athletes undergoing concurrent endurance and strength loads.

Reviews of vegetarian athletes generally report no significant differences in VO₂ max, power, sprint performance, or body composition, while vegetarians often consume more carbohydrate and less protein [26]. Broader assessments similarly conclude that plant-based diets can support exercise but require attention to protein density, leucine, iron, vitamin B12, vitamin D, calcium, zinc, iodine, and long-chain n-3 fatty acids [5,25,27]. Evidence specific to women remains too sparse for strong inference concerning menstrual function, hormonal adaptation, pregnancy, or injury risk in elite sport [29].

3.5. Synergistic effects on recovery and athletic performance

An integrated model is plausible. Adequate carbohydrate restores glycogen and reduces the need to oxidize amino acids; polyphenol- and micronutrient-rich foods may constrain excessive oxidative damage; fermentable carbohydrate supports SCFA production and barrier function; and adequately dosed complementary protein supplies EAAs for remodeling. Vascular and endothelial effects may assist nutrient and oxygen delivery, while lower chronic inflammatory tone may improve training availability [2,4]. Nevertheless, the chain from diet to microbiota or CRP to performance has rarely been tested within the same athlete trial.

Performance reviews consistently find maintenance rather than clear superiority. Plant-based diets may facilitate high carbohydrate availability and favorable body composition, but antinutrients, low energy density, high gastrointestinal bulk, and micronutrient gaps can become limiting during heavy training [4,25]. The literature on popular diets further indicates that no single pattern is universally appropriate and that restrictive implementation can be more consequential than dietary label [5].

Accordingly, recovery benefits should be described as conditional and mechanistically plausible, not as established ergogenic effects.

4. Practical Applications and Nutritional Recommendations

1. Secure energy availability first. Energy intake should be periodized to training load, body-composition goals, travel, and competition. High-fiber foods can lower dietary energy density; oils, nut and seed butters, avocado, tofu, tempeh, fortified beverages, refined grains around training, and liquid nutrition may be required during high-volume phases.
2. Set an individualized protein target. A practical range of approximately 1.6–2.2 g kg⁻¹ day⁻¹ is defensible for strength, power, and mixed-sport athletes, with the upper portion favored during energy restriction, injury rehabilitation, congested competition, or when protein quality is lower. The exact requirement was not directly established by the supplied athlete trials and should be individualized.
3. Distribute protein across the day. Four to five feedings containing approximately 0.3–0.4g/kg high-quality or complementary plant protein should be used, including a post-exercise feeding and, when compatible with energy needs, a pre-sleep feeding. Each principal meal should provide a robust EAA profile and approximately 2.5–3.0 g leucine; larger doses may be needed for whole-food sources or larger athletes [21,23,24,34].
4. Use complementary sources deliberately. Legume proteins should be combined across the day with cereal, seed, nut, soy, pea, potato, rice, canola, or fungal proteins. Soy is the best-supported single plant source in longitudinal evidence; pea–rice–canola and pea–canola blends have produced whey-comparable acute responses when adequately dosed or fortified [20,22,24,34,36].
5. Periodize fiber. Habitual intake should emphasize diverse vegetables, fruit, legumes, whole grains, nuts, and seeds to support saccharolytic fermentation. Fiber, fermentable oligosaccharides, and large pulse meals should be reduced immediately before high-intensity sessions or competition in athletes susceptible to bloating, urgency, or exercise-associated gastrointestinal symptoms [6,13,38].

6. Monitor nutrients at risk. Vitamin B12 supplementation is mandatory for fully vegan athletes. Iron status should be assessed with complete blood count, ferritin, transferrin saturation, and clinical context rather than supplemented empirically. Vitamin D, calcium, iodine, zinc, selenium, and long-chain n-3 status or intake require dietary review; creatine monohydrate may be particularly relevant where baseline dietary creatine is absent [27,29].
7. Prefer foods over chronic megadose antioxidants. Berries, cherries, pomegranate, cocoa, tea, herbs, spices, colorful vegetables, and extra-virgin olive oil can be concentrated during competition and short recovery windows, while routine high-dose isolated vitamins C and E should be avoided unless clinically indicated [30].
8. Treat probiotics as strain-specific interventions. Kefir and synbiotic studies provide preliminary signals, but benefits cannot be generalized across products. Selection should be based on strain, dose, indication, safety, and trial period rather than commercial claims [10,12].

5. Limitations and Future Research Directions

The principal limitation is that the review was bounded by uploaded sources and therefore cannot claim exhaustive retrieval. The corpus combined narrative reviews, systematic reviews, meta- analyses, acute tracer studies, cross-sectional observations, and small interventions, creating overlap and risk of double-counting underlying studies. Many data were derived from healthy adults rather than professional athletes; male participants predominated, dietary definitions varied, and few trials verified long-term adherence to a fully vegan diet. Microbiome studies used different sequencing regions, bioinformatic pipelines, sample handling, diversity indices, and metabolite assays.

Fecal measurements incompletely represent mucosal ecology or circulating microbial metabolites. CRP evidence was stronger than evidence for IL-6, TNF- α , gut permeability, illness incidence, or competition performance.

Future trials should recruit adequately powered professional-athlete cohorts stratified by sex, sport, ethnicity, training phase, and habitual diet. Controlled but ecologically valid interventions of at least one competitive season should compare a well-designed vegan diet with an energy-, carbohydrate-, and protein-matched omnivorous diet. Prespecified outcomes should include training availability, validated performance tests, competition metrics, illness and gastrointestinal symptom burden, body composition, menstrual and endocrine function, iron and micronutrient status, plasma and fecal metabolomics, shotgun metagenomics, barrier markers, and stable-isotope MPS. Repeated sampling is needed to distinguish transient training responses from stable adaptation. Trials should also test whether microbiome changes

mediate—rather than merely correlate with—changes in recovery or performance. The systematic-review literature itself calls for standardized methods, athlete-specific longitudinal designs, and mechanistic integration [7,8,11,16].

6. Conclusions

Plant-based diets are compatible with professional sport when energy and nutrient provision are deliberately engineered. The most defensible benefits are a modestly lower basal inflammatory burden, particularly CRP, and provision of fermentable substrates that can support SCFA-producing microbiota. Neither effect has been shown consistently to improve elite performance. For skeletal- muscle adaptation, protein source becomes less consequential when total intake is sufficient, meals are well distributed, and plant proteins are blended, processed, or fortified to provide adequate EAAs and leucine. Single-source proteins at equal modest doses may produce lower acute anabolic responses, while optimized blends can match whey and support comparable training-induced hypertrophy and strength. The primary clinical risk is not plant-based eating per se, but low energy availability, insufficient protein quality or dose, and unrecognized micronutrient deficiency. Individualized planning, biochemical surveillance, gastrointestinal periodization, and outcome-based reassessment are therefore required.

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