Scholastic Medical Sciences (ISSN: 3139-7352) Review Article

Volume 3 Issue 11 November 2026

Gut Microbiota and Sports Performance: A Critical Review of the Gut–Muscle Axis and Practical Nutritional Strategies

Rosario Adriana Reyes Díaz[1]* https://orcid.org/0000-0002-7007-7543, Verónica Pulido Herrera[1] https://orcid.org/0000-0002-2226-5734, Elizabeth Fonseca León[1] https://orcid.org/0000-0001-7045-6204, Nayeli Morales Barradas[1] https://orcid.org/0000-0001-7688-5624, Lorena Levet Rivera[1] https://orcid.org/0009-0008-5255-6998, Rubí del Rocío Sánchez Ramírez[1] https://orcid.org/0000-0001-6255-7507

Faculty of Nutrition, Veracruz Region, Universidad Veracruzana, Veracruz, Veracruz, Mexico.

Corresponding Author: Rosario Adriana Reyes Díaz, Faculty of Nutrition, Veracruz Region, Universidad Veracruzana, Veracruz, Veracruz, Mexico. **Email:** rosareyes@uv.mx

Received: October 30, 2026**; Published:** November 08, 2026

Abstract

The gut microbiota has gained importance in sports nutrition. It has been attributed a role in exercise adaptation, recovery, and muscle function through what is now known as the gut–muscle axis. The microbiota of athletes is known to differ from that of sedentary individuals, particularly in its metabolic function, and better cardiorespiratory fitness is usually accompanied by greater microbial diversity. What remains unclear is how much of this improves performance. This narrative review sought to separate what has been demonstrated in humans from what derives from animal models and, on that basis, to propose useful recommendations for the sports nutritionist. The literature published since 2014 in PubMed and Scopus was reviewed, and each finding was classified according to its level of evidence. The most studied mechanisms are the production of short-chain fatty acids, the conversion of lactate to propionate by bacteria of the genus Veillonella, the protection of the intestinal barrier, the relationship with mitochondrial function, and communication between the gut and the brain. Almost all of them have been described in mice. In humans, increasing short-chain fatty acids in the colon protected the intestinal barrier during exercise but did not improve aerobic performance. Nor did prebiotics improve aerobic capacity in the most recent meta-analysis, and probiotic trials are heterogeneous and often carry a high risk of bias. A stable microbiota during dietary periodization, sufficient fiber intake, and carbohydrate quality appear to matter more than any isolated supplement. Female athletes remain underrepresented, and aspects such as hormonal contraceptive use or low energy availability have barely been studied. It is concluded that the microbiota is a plausible, but not yet demonstrated, factor in sports performance. In the meantime, the most sensible approach in practice is to ensure sufficient and progressive fiber intake, adequate energy availability, and gradual dietary changes, and to reserve probiotics for specific goals using strains with demonstrated efficacy.

Keywords: gut microbiota; sports performance; gut–muscle axis; short-chain fatty acids; probiotics; dietary fiber

Abbreviations

AMPK: AMP-activated protein kinase

FODMAP: Fermentable oligosaccharides, disaccharides, monosaccharides, and polyols

I-FABP: Intestinal fatty acid-binding protein

IgA: Immunoglobulin A

IL-6: Interleukin 6

ISSN: International Society of Sports Nutrition

PGC-1α: Peroxisome proliferator-activated receptor γ coactivator 1α

RCT: Randomized controlled trial

RED-S: Relative energy deficiency in sport

SANRA: Scale for the Assessment of Narrative Review Articles

SCFA: Short-chain fatty acids

SIRT1: Sirtuin 1

TRPV1: Transient receptor potential vanilloid 1

VO_2max: Maximal oxygen uptake

Copyrights: @2026. Open Access by Scholastic is licensed under a Creative Commons Attribution 4.0 International License Based on a work at https://www.scholasticopenaccess.org/

Introduction

Few areas of nutrition have grown as quickly as the study of the gut microbiota. This is not surprising: a reference adult harbors around 38 trillion bacteria, a number very similar to that of their own cells, and most of them live in the colon [1]. These bacteria take part in nutrient absorption, synthesize vitamins, extract energy from food, and participate in the regulation of inflammation and the immune response. Their composition depends, among other factors, on age, mode of birth, antibiotic use and, very importantly, diet [2].

In sport, interest arose when it began to be proposed that the microbiota could influence exercise adaptation, recovery, and skeletal muscle function. This gave rise to the idea of the *gut–muscle axis*, a two-way communication in which metabolites produced by bacteria act as messengers between the gut and the muscle [3].

The first data in athletes were obtained in professional rugby players. Their microbiota was more diverse than that of men of similar size and age, and this diversity was related to protein intake and plasma creatine kinase. The authors themselves rightly cautioned that the relationship was not simple, because elite training is usually accompanied by an equally extreme diet [4]. When the same cohort was analyzed using metagenomics and metabolomics, the differences from sedentary individuals were even clearer at the functional than at the taxonomic level; athletes had, for example, a greater capacity to produce short-chain fatty acids (SCFA) such as acetate, propionate, and butyrate [5]. Another study, in healthy adults with comparable age, body mass index, and diet, showed that peak oxygen uptake explained more than 20% of the variation in species richness and that those with better fitness produced more butyrate [6].

Intervention studies pointed in the same direction. In previously sedentary adults, six weeks of aerobic training changed the composition and function of the microbiota, although differently in lean individuals and in those with obesity. Fecal SCFA increased only in the former, and most of the changes disappeared when they stopped training [7]. However, the work that truly sparked interest in the field was that on *Veillonella*. This genus increased in runners after a marathon, and when a strain of *Veillonella atypica* isolated from them was inoculated into mice, the animals ran longer before reaching exhaustion. The proposed explanation was that the bacterium converts the lactate produced during exercise into propionate; indeed, administering propionate reproduced the effect [8]. For the first time, it was suggested that the microbiota not only responds to exercise but could also contribute to performance.

From then on, interest grew in modifying the microbiota through diet and supplements. The International Society of Sports Nutrition (ISSN) described the characteristics of the athlete's microbiota and the factors that shape it [2] and published its position on the use of probiotics in athletes [9]. Since then, reviews have appeared on microbiota-targeted interventions to improve performance [10] and on the relationship between training and the microbiota in high-level athletes [11].

Even so, the evidence is far from conclusive. In combat sports, for example, studies include between 12 and 53 athletes, use very different methods, and most of the bacterial genera they report appear in a single study, so it is not possible to speak of a microbial signature specific to these sports [12]. Added to this is a problem well known in the sport sciences: women remain understudied, including with regard to gastrointestinal physiology, and how the microbiota, estrogens, and other bodily processes are related is still not well understood [13]. Against this background, translating the findings into clinical practice is not straightforward.

Therefore, the objective of this review was to critically analyze the mechanisms of the gut–muscle axis, separating the evidence obtained in humans from that derived from animal models, and to propose, on that basis, practical recommendations for the sports nutritionist.

2. Search Methods and Selection of the Literature

This is a critical narrative review. Its preparation followed the criteria of the SANRA scale (*Scale for the Assessment of Narrative Review Articles*), which evaluates the justification and objectives of the review, the description of the search, the use of references, scientific reasoning, and the presentation of data [14].

2.1 Information sources and search strategy. The literature search was conducted in PubMed/MEDLINE and Scopus between August and October, 2026.. Articles published from January 2014 onward were included, the year in which the first study on the gut microbiota of professional athletes appeared [4]. MeSH terms and free-text words from three groups were combined: gut microbiota; sport, exercise, and performance; and mechanisms and nutritional strategies. In addition, the reference lists of the selected articles were manually reviewed.

2.2 Eligibility criteria. Three types of studies were considered. The first, original studies in athletes or physically active adults (randomized controlled trials, cohort, cross-sectional, or case–control studies) that assessed the microbiota, or an intervention targeting it, in relation to performance, recovery, or related physiological markers. The second, animal studies, which were used only to explain mechanisms. The third, systematic reviews, meta-analyses, and position statements. Articles in English or Spanish published in peer-reviewed journals were accepted. Studies in people with any disease, in children or older adults, in military personnel, and in electronic sports players were excluded, as were conference abstracts, letters, and studies that neither measured the microbiota nor intervened on it.

2.3 Selection and synthesis of the evidence. The search yielded 1,005 records in PubMed and 664 in Scopus. After removing 482 duplicates, 1,187 titles and abstracts were reviewed and 375 were considered relevant. From these, the most recent and best-designed studies were chosen for each topic (n = 47), to which three methodological and contextual references identified through other sources were added, for a total of 50 references. Figure 1 summarizes the search and selection process, as well as the reasons for exclusion.

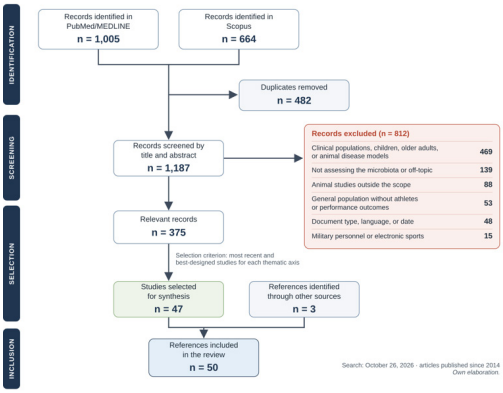


Figure 1: Flow diagram of the literature search and selection process. Own elaboration. It shows the records identified in each database, the duplicates removed, the records screened by title and abstract, the reasons for exclusion, and the number of references finally included in the review.

To make the critical appraisal explicit, each finding was classified according to its origin: level A, randomized controlled trials, systematic reviews, or meta-analyses in humans; level B, observational studies in humans; and level C, animal or *in vitro* studies. This classification appears in Tables 1, 2, and 3.

Study	Population	Design	Main finding	Level
Clarke et al. [4]	Professional rugby players (men) and controls	Cross-sectional	Greater diversity in athletes, correlated with protein and creatine kinase	B
Barton et al. [5]	Same rugby cohort	Cross-sectional, metagenomics and metabolomics	Larger differences at the functional level; more fecal SCFA	B
Estaki et al. [6]	39 healthy adults with varying fitness	Cross-sectional	VO_2peak explained >20% of taxonomic richness; more butyrate	B
Allen et al. [7]	Sedentary lean adults and adults with obesity	6-week intervention	Changes dependent on obesity status and reversible	B
Scheiman et al. [8]	Marathon runners and elite athletes; mice	Observational and experimental	*Veillonella* increased after the marathon; lactate-to-propionate conversion	B/C
Li et al. [19]	543 samples from athletes in three sports	Multi-cohort	Sport-specific microbiota; sex-dependent effects	B
Shalmon et al. [20]	22 runners (9 women) and 18 controls	Cross-sectional	Ten taxa correlated with VO_2max and time to exhaustion	B
Ampe et al. [23]	14 World Tour cyclists (women) and 13 controls	Cross-sectional	Lower diversity, more Bacteroidota, and fewer fiber fermenters	B
Fernandez-Sanjurjo et al. [22]	16 professional cyclists during a Grand Tour	Cohort	Bacterial family dynamics predicted performance; SCFA unrelated	B
Charlesson et al. [35]	23 highly trained rowers	Cohort	High load: less propionate and butyrate	B
Karl et al. [27]	12 active men	Crossover RCT	More SCFA and better intestinal barrier, with no improvement in 5-km time trial	A

Table 1: Key human studies on gut microbiota and sports performance.

SCFA: short-chain fatty acids; RCT: randomized controlled trial; VO_2max: maximal oxygen uptake. Level of evidence: A = clinical trials or systematic reviews in humans; B = observational studies in humans; C = animal models.

Study	Intervention	Population	Performance outcome	Level
Morita et al. [21]	α-cyclodextrin	Active men	Improved endurance performance	A
Torquati et al. [37]	15 g inulin (acute)	21 active men	No effect on 15-km time trial	A
Zha et al. [38]	Fiber 3.24 vs. 6.84 g/day, 8 weeks	20 basketball players	Improvements in both groups; no between-group differences or placebo	A (limited)
Chung [39]	Prebiotics (meta-analysis)	8 human RCTs and 7 animal studies	No significant improvement in VO_2max or endurance	A
Furber et al. [41]	High-carbohydrate or high-protein diet	Highly trained runners	+6.5% with carbohydrates; −23.3% with protein	A
Moreno-Pérez et al. [42]	Protein supplement, 10 weeks	24 cross-country runners	Fewer health-associated taxa; no changes in SCFA	A
Lin et al. [45]	*B. longum* OLP-01, 5 weeks	21 runners (7 women)	Improved Cooper test distance	A
Öneş et al. [46]	Kefir 200 mL/day, 28 days	21 professional soccer players (women)	Greater diversity; taxa associated with performance; no placebo	A (limited)
Jagłowska et al. [47]	Multistrain probiotic with standardized diet	27 runners (men)	No effect on VO_2peak, anaerobic performance, or inflammation	A
Porepp et al. [43]	Probiotics (systematic review)	9 RCTs, 216 participants	Seven with positive results; high risk of bias	A

Table 2: Microbiota-targeted nutritional interventions and performance in athletes or active individuals.

SCFA: short-chain fatty acids; RCT: randomized controlled trial; VO_2max: maximal oxygen uptake. Level of evidence: A = clinical trials or systematic reviews in humans; B = observational studies in humans; C = animal models.

Recommendation	Practical application	Level
Ensure sufficient fiber intake	Assess habitual intake; if <20 g/day, increase gradually to ~30 g/day over six weeks; reduce it temporarily only in the presence of symptoms or close to competition [36]	Expert opinion / C
Prioritize complex carbohydrates	Limit simple carbohydrates from supplements outside competition [22]	B
Periodize the diet gradually	Avoid abrupt changes in macronutrient proportions [41]	A
Take care with long-term protein supplementation	Cover protein with food and accompany it with fiber [42]	A (pilot)
Selective use of probiotics	Choose the strain according to the goal (gastrointestinal symptoms, respiratory infections) and evaluate the response; do not prescribe them routinely to improve performance [9, 44, 47]	A
Include fermented foods and polyphenols	Integrate them within a healthy dietary pattern [46, 48]	B/C
Ensure adequate energy availability	Detect low energy availability and RED-S risk [50]	C (hypothesis)
Consider female-specific variables	Record hormonal contraceptive use and menstrual status [49]	C
Do not prescribe based on commercial microbiome tests	There are no validated reference values [15, 17]	Expert opinion

Table 3: Practical recommendations for the sports nutritionist.

SCFA: short-chain fatty acids; RCT: randomized controlled trial; VO_2max: maximal oxygen uptake. Level of evidence: A = clinical trials or systematic reviews in humans; B = observational studies in humans; C = animal models.

Gut Microbiota: Basic Concepts

3.1 Definitions and composition. It is worth starting with the terms. The *gut microbiota* is the set of microorganisms that live in the digestive tract (bacteria, archaea, fungi, and viruses), whereas the *microbiome* refers to their genes and to what those genes enable them to do. Bacteria are by far the most abundant group and are concentrated mainly in the colon [1]. In healthy adults, two phyla predominate, Firmicutes (now Bacillota) and Bacteroidetes (Bacteroidota), but species-level composition is so particular to each person that it has been compared to a fingerprint [2].

3.2 Functions and shaping factors. In addition to helping absorb nutrients and synthesize vitamins, the microbiota obtains energy from dietary components that the body does not digest and participates in the regulation of inflammation and immunity [2]. In athletes, the usual factors (age, mode of birth, antibiotics, and diet) are joined by the type and load of training, the diet specific to each discipline, and the environmental conditions in which they train and compete [2].

3.3 What is a "healthy" microbiota? The question seems simple, but it still lacks a universally accepted answer. The term *dysbiosis* is very often used to relate microbial imbalances to diseases, although it has no precise definition. There is not even agreement on who should serve as a reference: people without disease? athletes at their peak? those who exercise and eat well? [15]. Because the microbiota varies so much between individuals and depends on diet, lifestyle, and environment, there are no reference values, and separating cause from effect remains one of the great challenges in the field [15]. Therefore, when this work refers to a "favorable profile" or "greater diversity," it refers to associations and not to clinical indicators.

3.4 How the microbiota is studied. In athletes, two sequencing techniques have mainly been used: 16S rRNA gene sequencing and *shotgun* metagenomics [16]. The first makes it possible to know which bacteria are present and in what proportion, although almost always only down to the genus level. The second sequences all the genetic material in the sample, so it identifies species and allows estimation of which metabolic pathways are present. The difference is not minor. In rugby players, for example, the differences compared with sedentary individuals were more evident with metagenomics and metabolomics than with compositional analysis [5]. Thanks to these techniques, attention has been paid to butyrate-producing bacteria such as *Faecalibacterium prausnitzii*, *Roseburia hominis*, and *Anaerostipes hadrus*, and to the activity of *Prevotella copri* and *Veillonella atypica* on branched-chain amino acids and lactate [16]. The underlying problem is that each group works with its own procedures and there are no reference data for athletes, which is why standardized protocols for collecting, analyzing, and handling samples have already been proposed [17].

The Athlete's Microbiota

4.1 Is there an "athletic microbiota"? Comparative studies indicate that exercise, the accompanying diet, and athletic status itself are associated with more health-related species, greater diversity, and greater metabolic capacity [2]. In rugby players, more *Akkermansia* and higher fecal SCFA concentrations were also found [5]. However, no one has been able to describe a core set of bacteria that characterizes the athlete. What does appear to exist are certain traits that could favor greater metabolic efficiency, largely through the production of metabolites such as SCFA [18].

4.2 Sport specificity. A study with 543 samples from aerobics, wrestling, and rowing athletes found that each sport had its own microbiota. The authors described ten microbial subgroups with different relationships to inflammation, diet, and anaerobic performance; most inflammatory markers were associated with a *Prevotella*-dominated subgroup, and the effect of sport type and exercise intensity was not the same in men and women [19]. In combat sports, by contrast, results agree little from one study to another [12].

4.3 Associations with performance markers. In competitive non-professional runners (13 men and 9 women) compared with physically inactive individuals, diversity differed between groups and ten taxa correlated with VO_2max, blood lactate, time to exhaustion, and weekly training volume. An interesting finding is that there were no differences between male and female runners [20]. In 25 long-distance runners, the abundance of *Bacteroides uniformis* was related to 3,000-m time [21]. And in professional cyclists followed during a Grand Tour, the dynamics of four bacterial families (Bifidobacteriaceae, Coriobacteriaceae, Erysipelotrichaceae, and Sutterellaceae) predicted the final result quite well. The authors concluded that it is more useful to look at the

community as a whole than to search for a particular bacterium [22]. All of these studies are observational (level B), so they do not allow conclusions about cause and effect.

4.4 Evidence in female athletes. Data in women are scarce and, interestingly, do not always follow the "more diversity" pattern. In professional cyclists of the World Tour circuit, the microbiota had more Bacteroidota (72.7% vs. 15.3% in controls), fewer Firmicutes (22.1% vs. 62.5%), lower diversity, and fewer fiber-fermenting families such as Lachnospiraceae and Ruminococcaceae. This profile is consistent with a diet heavily focused on carbohydrates and relatively low in fiber, although fecal SCFA were similar in both groups [23]. In female long-distance runners, the microbiota was also different from that of non-athletic women, and the concentration of succinate, an undesirable metabolite when it accumulates, was higher [24]. These results are a reminder that intense training and the accompanying diet do not always produce a more diverse microbiota, and that the response may not be the same in both sexes [19].

Mechanisms of the Gut–Muscle Axis

Figure 2 summarizes the proposed mechanisms and the level of evidence supporting each one.

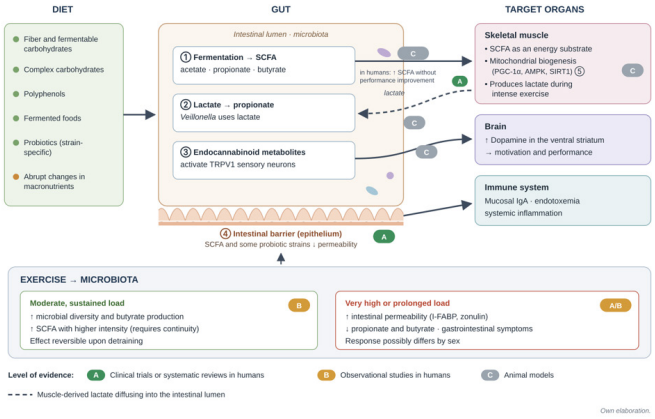


Figure 2: Integrative model of the gut–muscle axis in athletes and level of evidence for each pathway. (Own elaboration). Dietary components modulate the gut microbiota, which acts through five pathways: (1) fermentation of fiber and fermentable carbohydrates produces short-chain fatty acids (SCFA), proposed as an energy substrate for muscle; in humans, increasing SCFA did not improve performance; (2) lactate produced by muscle during exercise diffuses into the intestinal lumen and Veillonella converts it into propionate; (3) endocannabinoid metabolites of microbial origin activate TRPV1 sensory neurons and increase dopamine in the ventral striatum; (4) SCFA and some probiotic strains protect the intestinal barrier and reduce permeability, with effects on mucosal immunity and systemic inflammation; and (5) the microbiota interacts with mitochondrial biogenesis (PGC-1α, AMPK, SIRT1). The lower panel shows the effect of exercise on the microbiota according to training load. A = clinical trials or systematic reviews in humans; B = observational studies in humans; C = animal models.

5.1 Short-chain fatty acids and energy metabolism. Acetate, propionate, and butyrate are formed when bacteria ferment the carbohydrates that reach the colon. They influence nutrient metabolism, energy balance, and immune function, both local and systemic, although in humans neither their mechanisms nor their practical application are yet well understood [25]. The most striking data come from mice: when the microbiota was eliminated with antibiotics or the animals were given a diet low in fermentable carbohydrates, their endurance and plasma SCFA decreased, and continuous acetate infusion restored their exercise capacity (level C) [26]. Also in mice, administering *B. uniformis* prolonged swimming time, raised cecal SCFA, and increased hepatic expression of gluconeogenic enzymes; in active men, α-cyclodextrin, a substrate that favors this bacterium, improved endurance performance in a randomized trial [21].

When attempts are made to translate this to humans, however, the results are more modest. In a double-blind crossover trial, 12 active men consumed a starch modified to release SCFA in the colon. Their fecal and serum SCFA increased, markers of intestinal damage and permeability decreased, and the respiratory exchange ratio rose slightly; but glucose turnover, muscle glycogen use, and time in a 5-km time trial did not change (level A) [27]. Nor was any relationship found between fecal SCFA and performance in the cycling Grand Tour [22]. With the evidence available so far, SCFA appear important for protecting the gut, but there is no proof that they act as an ergogenic fuel in humans.

5.2 Lactate, *Veillonella* , and propionate. In mice, it was shown that blood lactate can pass into the intestinal lumen, where *Veillonella*, which uses it as its sole carbon source, converts it into propionate. Both the bacterium and propionate increased the animals' running time, and in elite athletes all genes of the lactate-to-propionate conversion pathway were more abundant after exercise [8]. In adults with metabolic syndrome, only the most intense training increased fecal SCFA, and this increase correlated with the mean lactate reached during the sessions ($r = 0.68$) [28]. This finding supports the idea of a lactate-mediated microbial adaptation, but there are still no studies demonstrating an ergogenic effect of *Veillonella* in humans.

5.3 Intestinal permeability, endotoxemia, and inflammation. Anyone who has worked with runners or triathletes knows that gastrointestinal symptoms are common, especially as intensity, temperature, or distance increase. Prolonged ischemia, mechanical damage to the epithelium, and loss of barrier integrity have been proposed as causes, in combination with neuroendocrine, microbial, and nutritional factors [29]. A systematic review found thirteen studies with negative effects of intense or prolonged aerobic exercise (increases in I-FABP, permeability, zonulin, and *Prevotella*) versus seven with positive effects, and adverse effects were more frequent in athletes than in non-athletes [30]. In a small crossover trial with seven adults, four weeks of the probiotic strain UCC118 reduced sucrose permeability after running, although not lactulose or rhamnose permeability, and did not modify plasma IL-6 or fecal zonulin [31]. As mentioned above, increasing SCFA in the colon also helped preserve barrier function during exercise [27].

5.4 Mitochondria and oxidative stress. It has been proposed that the microbiota and some of its metabolites, such as SCFA and secondary bile acids, influence PGC-1α, SIRT1, and AMPK, key molecules in the formation of new mitochondria, as well as energy production, reactive oxygen species, and inflammation. The relationship would work in both directions, since mitochondria, in turn, influence the intestinal barrier and the mucosal immune response [32]. Almost all of this evidence, however, is preclinical (level C).

5.5 Gut–brain axis. One of the most suggestive findings of recent years was obtained in mice. The microbiota produces endocannabinoid metabolites that stimulate sensory neurons with TRPV1 receptors, which increases dopamine in the ventral striatum during exercise and improves running performance. When the microbiota was eliminated or this pathway was blocked, the animals ran less [33]. The idea that part of the motivation to train depends on the gut is appealing and could help explain why some people perform better than others, but it has not yet been confirmed in humans.

Effect of Exercise on the Microbiota

The relationship also works in the opposite direction: exercise modifies

the microbiota. In sedentary adults, the changes produced by training depended on whether or not the person had obesity, and they were lost after training stopped [7]. In other words, the effect exists, but it requires continuity. A pilot meta-analysis found that the type and intensity of exercise modify the Bacillota/Bacteroidota ratio [34]. Intensity, in fact, seems to matter considerably: when data from three randomized trials in adults with metabolic syndrome were pooled, only high-intensity interval training increased fecal SCFA, by about 30% [28].

However, more exercise is not always better for the gut. The systematic review on intense and prolonged exercise found mainly negative effects on the microbiota and the intestinal barrier [30]. In 23 high-level rowers, periods of greater load coincided with less propionate and butyrate, less frequent bowel movements, and a trend toward lower diversity, even though macronutrient intake remained stable [35]. Everything seems to indicate a dose–response relationship: moderate loads would favor a healthy profile, and extreme loads could disrupt intestinal balance.

7. Nutritional Modulation of the Microbiota in Athletes

7.1 Fiber and prebiotics. It is striking that sports nutrition guidelines, so detailed regarding carbohydrates, say nothing about fiber, even though in practice it is frequently adjusted to manage gastrointestinal comfort or body composition. It has recently been proposed to assess each athlete's habitual intake and, when it is below 20 g/day, to increase it gradually to about 30 g/day (with around 2 g of beta-glucans) over six weeks, in order to maintain microbiota diversity and stability, the intestinal barrier, and SCFA production [36]. Expecting an immediate effect on performance is another matter. A 15-g dose of inulin did not change 15-km time-trial performance or plasma acetate in 21 active men [37]. In basketball players who received 3.24 or 6.84 g/day of additional fiber for eight weeks, both groups improved their body composition and performance without differences between them; since there was no placebo group, the improvement cannot be attributed to the fiber [38]. A meta-analysis published this year, with eight human trials and seven animal studies, found no improvements in aerobic capacity or endurance with isolated prebiotics (very low GRADE certainty), although it did find favorable effects on mucosal immunity [39]. Overall, prebiotics appear more useful for protecting the intestinal barrier, reducing digestive symptoms, increasing salivary IgA, and decreasing respiratory symptoms than for improving performance [40].

7.2 Carbohydrates, protein, and dietary periodization. The type of carbohydrate the athlete consumes matters. During the cycling Grand Tour, the abundance of Erysipelotrichaceae was related to the prior intake of foods rich in complex carbohydrates, whereas that of Bifidobacteriaceae decreased as simple carbohydrates from supplements increased [22]. In highly trained long-distance runners, a high-carbohydrate diet improved time-trial performance by 6.5% and a high-protein diet worsened it by 23.3%. Most interestingly, those whose microbiota changed least performed better [41]. Protein requires nuance. In rugby players its intake was related to greater diversity [4], but in cross-country runners, ten weeks of a whey and beef protein supplement increased Bacteroidetes and reduced health-associated bacteria such as *Roseburia*, *Blautia*, and *Bifidobacterium longum* [42]. It must be acknowledged, in any case, that it is very difficult to isolate the effect of a single dietary component [18].

7.3 Probiotics. The ISSN makes it clear that the benefits of probiotics depend on the strain. Some strains can reduce the number, severity, and duration of respiratory infections, decrease digestive discomfort, and improve the intestinal barrier, provided that the doses tested in the studies of each strain are used; the society itself acknowledges that the evidence on performance is limited [9]. Systematic reviews confirm this. One of them, with nine trials and 216 participants, found positive results in seven, but most with a high risk of bias [43]. Another, with 41 studies, described an enormous variety of strains, formulations, training levels, durations, and outcomes, and concluded that it is not possible to know whether probiotics improve immunity, respiratory infections, or gastrointestinal symptoms [44]. There are positive trials: *Bifidobacterium longum* OLP-01 increased the distance covered in the Cooper test in 21 middle- and long-distance runners [45], and 200 mL of kefir daily for 28 days increased diversity, *Akkermansia muciniphila*, and *F. prausnitzii* in professional female soccer players, bacteria that were also related to their performance, although the study had no placebo group [46]. But when the diet is fully controlled, the picture changes. In 27 runners who ate exactly the same food for four weeks, a multistrain probiotic did not modify VO_2peak, anaerobic performance, or inflammatory markers [47]. The better designed the study, the smaller the effect tends to be.

7.4 Polyphenols and fermented foods. Polyphenols have a prebiotic effect that favors microorganisms such as *A. muciniphila* and *Lactobacillus*. In addition, they could reduce exercise-induced inflammation, protect the gut, and improve endothelial function, although much of what is known comes from mechanistic studies [48]. Fermented foods, such as kefir, are an interesting dietary option, with still preliminary data in female athletes [46].

7.5 Synthesis of the reviewed evidence. Table 4 integrates what was presented in Sections 4 to 7. For each thematic axis, it summarizes the available evidence in humans and in animal models, the predominant level of evidence, and its implications for the practice of the sports nutritionist.

Table 4. Synthesis of the evidence on gut microbiota and sports performance.

Thematic axis	Evidence in humans	Evidence in animal models	Level	Practical implication
Athlete microbiota	Greater diversity and functional capacity than in sedentary individuals; the profile varies by sport, load, diet, and sex [5, 6, 19, 23]	—	B	There is no "ideal" reference profile
SCFA as an energy substrate	Increasing colonic SCFA did not improve time-trial performance or spare glycogen [27]	Microbiota depletion reduces endurance; acetate restores it [26]	C (A with no effect)	Do not use fiber or SCFA for acute ergogenic purposes
Lactate → propionate (*Veillonella*)	More pathway genes after exercise; lactate is associated with the increase in SCFA [8, 28]	*V. atypica* or propionate increase running time [8]	C	Hypothesis pending confirmation
Intestinal barrier	SCFA and strain UCC118 reduce permeability; intense exercise increases it [27, 30, 31]	—	A/B	Protective benefit, relevant under high loads
Mitochondria	—	Regulation of PGC-1α, SIRT1, and AMPK [32]	C	No practical application for now

Thematic axis	Evidence in humans	Evidence in animal models	Level	Practical implication
Gut–brain axis	—	Endocannabinoids → TRPV1 → dopamine [33]	C	No practical application for now
Effect of exercise	Moderate load: more diversity and SCFA; extreme load: less SCFA and more permeability [7, 28, 30, 35]	—	A/B	Monitor digestive symptoms during high-load periods
Fiber and prebiotics	No improvement in aerobic capacity; immune and barrier benefits [37, 39, 40]	Endurance gains mediated by SCFA [39]	A	Reach ~30 g/day of fiber progressively [36]
Carbohydrates, protein, and periodization	Microbial stability is associated with better performance; supplemental protein reduces beneficial taxa [22, 41, 42]	—	A/B	Gradual changes; prioritize complex carbohydrates
Probiotics	Inconsistent results; the most rigorous trials show no effect [43, 44, 47]	—	A	Selective use according to strain and goal
Female athletes	Scarce evidence; fewer SCFA producers in contraceptive users (pilot study) [23, 24, 49]	—	B/C	Record contraceptive use and menstrual status

SCFA: short-chain fatty acids; RCT: randomized controlled trial; VO_2max: maximal oxygen uptake. Level of evidence: A = clinical trials or systematic reviews in humans; B = observational studies in humans; C = animal models.

Discussion

8.1 Synthesis of the evidence. If this review makes one thing clear, it is the gap that still exists between what is biologically plausible and what has been demonstrated in humans. SCFA production, the conversion of lactate to propionate, gut–brain signaling, and the relationship with mitochondria have been described mainly in mice (level C) [8, 26, 32, 33]. In humans, observational studies agree that physical fitness is associated with a more diverse microbiota with greater functional capacity (level B) [5, 6, 19]. However, when attempts have been made to modify the microbiota or its metabolites to improve performance, the results have been modest, contradictory, or null (level A) [27, 37, 39, 47]. Some recent reviews present the gut–muscle axis as a promising target for sports nutrition [3], and it probably is; but when the evidence is ordered by level, it is observed that this promise has not yet become a demonstrated improvement in performance.

Two ideas help to look at the topic differently. The first is that the most consistent benefit of these interventions in humans is protective rather than ergogenic: they preserve the intestinal barrier, reduce digestive symptoms, and support mucosal immunity [27, 31, 39, 40]. For an athlete this is no small matter, because it allows training with greater continuity and better tolerance of food intake during exertion. The second is that a stable microbiota seems more valuable than an "ideal" microbiota. Those whose microbiota changed least during dietary periodization performed better [41], and very high training loads were associated with disturbances of the intestinal ecosystem [30, 35]. This is consistent with the absence of a core bacterial set specific to athletes [18] and with how difficult it is to define a healthy microbiota [15].

8.2 Limitations of the evidence. The available literature has several weaknesses. Most studies are cross-sectional, so it is not possible to know whether the microbiota influences performance or whether training modifies the microbiota [15]. Methods vary widely from one study to another, there are no reference values, and diet is rarely controlled, which complicates any comparison [16, 17]. Samples are usually small and the reported bacteria change from one study to another [12]. And what works in mice is not always reproduced in humans [27, 39].

In addition, women remain underrepresented [13]. Few studies include female athletes [23, 24, 46], and, to the best of current knowledge, only one pilot study has simultaneously analyzed hormonal contraceptives, the microbiota, and exercise in athletes; in it, contraceptive users had fewer SCFA-producing bacteria [49]. Likewise, it is reasonable to think that the microbiota participates in the relationship between low energy availability, RED-S, and bone health, but this has not yet been studied directly in athletes [50].

8.3 Limitations of this review. As a narrative review, study selection was not based on a registered protocol and did not include a formal risk-of-bias assessment. In addition, the search was limited to two databases and to articles in English or Spanish, and the journal's limit of 50 references required prioritizing the most recent and highest-quality studies. To compensate for these limitations as far as possible, the search and selection criteria were described in detail, and each finding was classified according to the type of evidence.

8.4 Future directions. Randomized trials with sufficient sample size, primary outcomes defined in advance, controlled diet, and direct measurement of the microbiome are needed [47]. It would also be desirable to combine metagenomics with metabolomics, to use standardized sampling and analysis procedures [17], and to consider sex, menstrual cycle phase, contraceptive use, and energy availability from the design stage.

9. Practical Recommendations for the Sports Nutritionist

Table 3 brings together the recommendations that emerge from the evidence, together with the level supporting each one. The first step is to review how much fiber the athlete consumes and, if it is low, to increase it gradually, leaving temporary reductions for the days close to competition or for when digestive symptoms occur [36]. Outside competition, priority should be given to complex carbohydrates and minimally processed foods [22], and abrupt dietary changes should be avoided by periodizing progressively [41]. Protein should be covered, as far as possible, with food and accompanied by fiber, especially when supplements are used over long periods [42].

Regarding probiotics, routine use to improve performance is not recommended. They may be considered in specific situations, such as digestive symptoms or recurrent respiratory infections during high-load phases, choosing a strain with evidence for that goal and evaluating each athlete's response [9, 44]. Fermented foods and sources of polyphenols have a place within a healthy diet [48]. It is also important to ensure adequate energy availability [50] and, in the case of female athletes, to ask about hormonal contraceptive use [49]. Finally, basing prescription on commercial microbiome tests is not advised, because there are still no reference values that allow them to be interpreted [15, 17].

Conclusions

The microbiota of athletes differs from that of sedentary individuals, especially in what it is capable of doing, and better cardiorespiratory fitness is associated with greater diversity and greater butyrate production. Even so, one cannot speak of a single "athletic microbiota," because its profile changes according to sport, training load, diet, and sex, and does not always imply greater diversity. The mechanisms used to explain its effect on performance, such as the production of short-chain fatty acids, the conversion of lactate to propionate, communication with the brain, or the relationship with mitochondria, have been described mainly in animals, and none has yet demonstrated an ergogenic effect in trials with athletes.

What is observed in humans is a protective benefit. Microbiota-targeted interventions help preserve the intestinal barrier during exercise, reduce digestive symptoms, and support mucosal immunity, and this may translate, indirectly, into greater training continuity and better tolerance of food intake during exertion. Moreover, keeping the microbiota stable seems more important than pursuing an ideal profile, since abrupt dietary changes and extreme training loads are associated with intestinal disturbances and even with poorer performance. In the case of female athletes, the available information is not yet sufficient to make specific recommendations, and topics such as hormonal contraceptives, the menstrual cycle, or low energy availability are only beginning to be studied.

For all these reasons, it is considered that the gut microbiota should, for now, be viewed as a factor that influences the athlete's digestive health and training tolerance rather than as a proven pathway to improve performance. In practice, the most advisable approach is to rely on diet: sufficient fiber, introduced gradually, good-quality carbohydrates, gradual dietary changes, and adequate energy availability. Probiotics should be reserved for specific goals and chosen according to the strain and dose that have demonstrated efficacy. To move forward, better-designed trials are needed, with controlled diet, performance outcomes defined in advance, direct analysis of the microbiome and its metabolites, and genuine participation of female athletes.

Declarations

Funding

This research received no external funding.

Declaration on the use of artificial intelligence

Generative artificial intelligence tools were used as support in the literature search, the preparation of Figures 1 and 2, and the translation into English. The authors reviewed and validated all content, verified the references, and assume full responsibility for the accuracy, integrity, and scientific content of the article.

References

1. Sender, Ron, et al. (2016) "Revised Estimates for the Number of Human and Bacteria Cells in the Body." *PLoS Biology*, vol. 14, no. 8, e1002533.
2. Mohr, Alex E., et al. (2020) "The Athletic Gut Microbiota." *Journal of the International Society of Sports Nutrition*, vol. 17, no. 1, p. 24.
3. Zhang, Xinbao, et al. (2026) "Microbiome-Based Nutrition and the Gut–Muscle Axis: Emerging Perspectives for Athletic Performance and Recovery." *Frontiers in Nutrition*, vol. 13, p. 1927715.
4. Clarke, Siobhan F., et al. (2014) "Exercise and Associated Dietary Extremes Impact on Gut Microbial Diversity." *Gut*, vol. 63, no. 12, pp. 1913–1920.
5. Barton, Wiley, et al. (2018) "The Microbiome of Professional Athletes Differs from That of More Sedentary Subjects in Composition and Particularly at the Functional Metabolic Level." *Gut*, vol. 67, no. 4, pp. 625–633.
6. Estaki, Mehrbod, et al. (2016) "Cardiorespiratory Fitness as a Predictor of Intestinal Microbial Diversity and Distinct Metagenomic Functions." *Microbiome*, vol. 4, no. 1, p. 42.
7. Allen, Jacob M., et al. (2018) "Exercise Alters Gut Microbiota Composition and Function in Lean and Obese Humans." *Medicine and Science in Sports and Exercise*, vol. 50, no. 4, pp. 747–757.
8. Scheiman, Jonathan, et al. (2019) "Meta-Omics Analysis of Elite Athletes Identifies a Performance-Enhancing Microbe That Functions via Lactate Metabolism." *Nature Medicine*, vol. 25, no. 7, pp. 1104–1109.
9. Jäger, Ralf, et al. (2019) "International Society of Sports Nutrition Position Stand: Probiotics." *Journal of the International Society of Sports Nutrition*, vol. 16, no. 1, p. 62.
10. Patel, Bharati Kadamb, et al. (2024) "Intestinal Microbiota Interventions to Enhance Athletic Performance—A Review." *International Journal of Molecular Sciences*, vol. 25, no. 18, p. 10076.
11. Carlone, Junior, et al. (2025) "The Performance Gut: A Key to Optimizing Performance in High-Level Athletes: A Systematic Scoping Review." *Frontiers in Sports and Active Living*, vol. 7, p. 1641923.
12. Carlone, Junior, et al. (2026) "Exploring the Gut Microbiome in Combat Sports: A Systematic Scoping Review." *Sports*, vol. 14, no. 1, p. 19.
13. Pugh, Jamie N., et al. (2022) "More than a Gut Feeling: What Is the Role of the Gastrointestinal Tract in Female Athlete Health?" *European Journal of Sport Science*, vol. 22, no. 5, pp. 755–764.
14. Baethge, Christopher, et al. (2019) "SANRA—A Scale for the Quality Assessment of Narrative Review Articles." *Research Integrity and Peer Review*, vol. 4, p. 5.
15. Van Hul, Matthias, et al. (2024) "What Defines a Healthy Gut Microbiome?" *Gut*, vol. 73, no. 11, pp. 1893–1908.
16. Sabater, Carlos, et al. (2023) "Next-Generation Sequencing of the Athletic Gut Microbiota: A Systematic Review." *Microbiome Research Reports*, vol. 2, no. 1, p. 5.
17. Mancin, Laura, et al. (2024) "Standardization of Gut Microbiome Analysis in Sports." *Cell Reports Medicine*, vol. 5, no. 10, p. 101759.
18. Pérez-Castillo, Í. M., et al. (2024) "The Athlete Gut Microbiota: State of the Art and Practical Guidance." *Beneficial Microbes*, vol. 15, no. 2, pp. 97–126.
19. Li, Yuxue, et al. (2023) "Gut Microbiota and Inflammation Patterns for Specialized Athletes: A Multi-Cohort Study across Different Types of Sports." *mSystems*, vol. 8, no. 4, e0025923.
20. Shalmon, Guy, et al. (2024) "Gut Microbiota Composition Positively Correlates with Sports Performance in Competitive Non-Professional Female and Male Runners." *Life*, vol. 14, no. 11, p. 1397.

21. Morita, Hiroto, et al. (2023) "Bacteroides uniformis and Its Preferred Substrate, α-Cyclodextrin, Enhance Endurance Exercise Performance in Mice and Human Males." *Science Advances*, vol. 9, no. 4, eadd2120.

22. Fernandez-Sanjurjo, Manuel, et al. (2024) "Dynamics of Gut Microbiota and Short-Chain Fatty Acids during a Cycling Grand Tour Are Related to Exercise Performance and Modulated by Dietary Intake." *Nutrients*, vol. 16, no. 5, p. 661.

23. Ampe, Toon, et al. (2025) "Nutritional and Physiological Demands Shape the Gut Microbiome of Female World Tour Cyclists." *Microorganisms*, vol. 13, no. 10, p. 2345.

24. Morishima, So, et al. (2021) "Intensive, Prolonged Exercise Seemingly Causes Gut Dysbiosis in Female Endurance Runners." *Journal of Clinical Biochemistry and Nutrition*, vol. 68, no. 3, pp. 253–258.

25. Bongiovanni, Tindaro, et al. (2021) "The Athlete and Gut Microbiome: Short-Chain Fatty Acids as Potential Ergogenic Aids for Exercise and Training." *International Journal of Sports Medicine*, vol. 42, no. 13, pp. 1143–1158.

26. Okamoto, Takuya, et al. (2019) "Microbiome Potentiates Endurance Exercise through Intestinal Acetate Production." *American Journal of Physiology. Endocrinology and Metabolism*, vol. 316, no. 5, pp. E956–E966.

27. Karl, J. Philip, et al. (2026) "Increasing Gut Short-Chain Fatty Acids Protects Intestinal Barrier Function but Does Not Spare Muscle Glycogen or Impact Aerobic Performance." *The Journal of Physiology*, vol. 604, no. 17, pp. 7161–7209.

28. Reljic, Dejan, et al. (2025) "Exercise Improves Gut Microbial Metabolites in an Intensity-Dependent Manner: A Pooled Analysis of Randomized Controlled Trials." *Gut Microbes*, vol. 17, no. 1, p. 2579354.

29. Smith, Kyle A., et al. (2021) "Gastrointestinal Pathophysiology during Endurance Exercise: Endocrine, Microbiome, and Nutritional Influences." *European Journal of Applied Physiology*, vol. 121, no. 10, pp. 2657–2674.

30. Bonomini-Gnutzmann, Romina, et al. (2022) "Effect of Intensity and Duration of Exercise on Gut Microbiota in Humans: A Systematic Review." *International Journal of Environmental Research and Public Health*, vol. 19, no. 15, p. 9518.

31. Axelrod, Christopher L., et al. (2019) "UCC118 Supplementation Reduces Exercise-Induced Gastrointestinal Permeability and Remodels the Gut Microbiome in Healthy Humans." *Physiological Reports*, vol. 7, no. 22, e14276.

32. Clark, Allison, and Núria Mach. Et al: (2017) "The Crosstalk between the Gut Microbiota and Mitochondria during Exercise." *Frontiers in Physiology*, vol. 8, p. 319.

33. Dohnalová, Lenka, et al. (2022) "A Microbiome-Dependent Gut–Brain Pathway Regulates Motivation for Exercise." *Nature*, vol. 612, no. 7941, pp. 739–747.

34. Ghaffar, Tehreema, et al. (2024) "The Role of Gut Microbiota in Different Types of Physical Activity and Their Intensity: Systematic Review and Meta-Analysis." *Sports*, vol. 12, no. 8, p. 221.

35. Charlesson, B., et al. (2025) "Training Load Influences Gut Microbiome of Highly Trained Rowing Athletes." *Journal of the International Society of Sports Nutrition*, vol. 22, no. 1, p. 2507952.

36. Mancin, Laura, et al. (2025) "Fibre: The Forgotten Carbohydrate in Sports Nutrition Recommendations." *Sports Medicine*, vol. 55, no. 5, pp. 1067–1083.

37. Torquati, L., et al. (2025) "The Role of Fermentable Fibre on Endurance Exercise Capacity: A Randomised Crossover Trial of Inulin Supplementation." *Nutrition Bulletin*, vol. 50, no. 3, pp. 447–458.

38. Zha, Yu, et al. (2025) "High-Dose Dietary Fibre Supplementation Enhances the Gut Microbiome, Health, and Athletic Performance of College Basketball Players." *International Journal for Vitamin and Nutrition Research*, vol. 95, no. 5,, p. 37069.

39. Chung, Y. Et al: (2026) "Prebiotic Modulation of the Gut–Muscle Axis and Moderate Exercise Performance: A Systematic Review and Meta-Analysis." *Translational Journal of the American College of Sports Medicine*, vol. 11, no. 3.

40. Sage, Sean A., et al. (2026) "Prebiotics in Sport and Exercise: Current Evidence, Practical Applications, and Methodological Considerations." *Journal of the International Society of Sports Nutrition*, vol. 23, no. 1, p. 2748763.

41. Furber, Matthew J. W., et al. (2022) "Gut Microbial Stability Is Associated with Greater Endurance Performance in Athletes Undertaking Dietary Periodization." *mSystems*, vol. 7, no. 3, e0012922.

42. Moreno-Pérez, Diego, et al. (2018) "Effect of a Protein Supplement on the Gut Microbiota of Endurance Athletes: A Randomized, Controlled, Double-Blind Pilot Study." *Nutrients*, vol. 10, no. 3, p. 337.

43. Porepp, Olavo da Silva Carvalho, et al. (2024) "Effect of Probiotic Supplementation on Gut Microbiota and Sport Performance in Athletes and Physically Active Individuals: A Systematic Review." *Journal of Dietary Supplements*, vol. 21, no. 5, pp. 660–676.

44. Heimer, Melina, et al. (2022) "Health Benefits of Probiotics in Sport and Exercise—Non-Existent or a Matter of Heterogeneity? A Systematic Review." *Frontiers in Nutrition*, vol. 9, p. 804046.

45. Lin, Che-Li, et al. (2020) "Bifidobacterium longum subsp. longum OLP-01 Supplementation during Endurance Running Training Improves Exercise Performance in Middle- and Long-Distance Runners: A Double-Blind Controlled Trial." *Nutrients*, vol. 12, no. 7, p. 1972.

46. Öneş, Ece, et al. (2025) "Effects of Kefir Consumption on Gut Microbiota and Athletic Performance in Professional Female Soccer Players: A Randomized Controlled Trial." *Nutrients*, vol. 17, no. 3, p. 512.

47. Jagłowska, Katarzyna, et al. (2026) "Multistrain Probiotic Supplementation Combined with a Standardized Diet Did Not Significantly Affect Exercise Performance or Inflammatory Responses in Male Endurance Runners: A Randomized Controlled Trial." *Nutrients*, vol. 18, no. 15, p. 2484.

48. Spears, Meghan L., et al. (2026) "Polyphenols, Gut Microbiota, and Exercise Triad Supports Performance." *The Journal of Nutrition*, vol. 156, no. 10, p. 101791.

49. Pierudzka, Weronika, et al. (2025) "Hormonal Contraceptives and the Gut Microbiome in Female Athletes: Implications for Health, Performance, and Exercise-Related Physiological Adjustments." *Cureus*, vol. 17, no. 7, e88789.

50. Wagner, Adam, et al. (2026) "Low Energy Availability, the Gut Microbiome, and Bone Health in Athletes: A Mechanistic Narrative Review Based on Athlete Evidence and Clinical Analogues." *Frontiers in Nutrition*, vol. 13, p. 1901299.