



QUALITY IN SPORT

eISSN 2450-3118 · Open Access · Peer-reviewed

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ZUZAK, Andrzej Paweł, MIODUSZEWSKA, Joanna, ROGUSKA, Zofia, SIM, Aleksandra, ROT, Paweł, PONIEWOZIK, Piotr, PONIEWOZIK, Paweł, GRABOWSKI, Krzysztof, PERNAL, Maja, and DZIUBA, Natalia. Lactose Restriction and Lactose-free Dairy Products in Athletes with Irritable Bowel Syndrome and Exercise-associated Gastrointestinal Symptoms: Implications for Performance, Hydration, and Recovery. *Quality in Sport*. 2026;71:75146. <https://doi.org/10.12775/QS.2026.71.75146>

ARTICLE TIMELINE

Received: 09.08.2026. Revised: 28.08.2026. Accepted: 05.09.2026. Published: 13.09.2026.

The journal has been awarded 20 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32553). Unique Journal Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).

Punkty Ministerialne z 2019 – aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych). © The Authors 2026.

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Lactose Restriction and Lactose-free Dairy Products in Athletes with Irritable Bowel Syndrome and Exercise-associated Gastrointestinal Symptoms: Implications for Performance, Hydration, and Recovery

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Abstract

Background: Gastrointestinal symptoms are common among athletes, particularly in endurance sports. Lactose intolerance, irritable bowel syndrome (IBS), and exercise-associated gastrointestinal symptoms may overlap, making dietary management challenging.

Aim of study: The aim of this review was to assess the role of lactose restriction and lactose-free dairy products in athletes with IBS or exercise-associated gastrointestinal symptoms.

Methodology: The review included studies published in the last 10 years and indexed in the PubMed database. The analysis covered publications on athletes, IBS, lactose intolerance, lactose malabsorption, lactose-free dietary strategies, hydration, recovery, and sports nutrition.

Results: Lactose restriction may improve gastrointestinal tolerance in selected athletes, particularly those with confirmed lactose intolerance or lactose-related symptoms. Lactose-free dairy products may help maintain adequate nutrient intake and may support hydration and recovery. However, routine lactose elimination is not supported in all athletes with gastrointestinal complaints.

Conclusions: Lactose restriction may be useful in selected athletes but should remain individualized. Unnecessary long-term dairy restriction should be avoided.

Keywords: athletes, lactose intolerance, lactose-free diet, IBS, exercise-associated gastrointestinal symptoms, sports nutrition, hydration, recovery

1. Introduction

Gastrointestinal symptoms are common among physically active individuals, particularly endurance athletes, and may include abdominal pain, bloating, nausea, diarrhea, urgency, and excessive gas production. Their development is associated with exercise intensity and duration, reduced splanchnic blood flow, altered gastrointestinal motility, dehydration, environmental conditions, and nutritional intake before and during exercise [1-2]. These complaints may impair exercise tolerance, interfere with nutritional and hydration strategies, and negatively affect training and sports performance. The problem may be particularly relevant in athletes with irritable bowel syndrome (IBS), as symptoms typical of IBS substantially overlap with exercise-associated gastrointestinal symptoms. IBS also appears to be underdiagnosed and inadequately managed among endurance athletes [3].

Dietary modification is commonly used by athletes attempting to prevent or reduce gastrointestinal complaints. Dairy products are among the foods frequently restricted, and lactose has been identified as one of the commonly avoided FODMAP components among athletes reporting food-related gastrointestinal symptoms [4]. Lactose malabsorption results from insufficient lactase activity, whereas lactose intolerance refers to gastrointestinal symptoms occurring after lactose consumption. Importantly, lactose intolerance and lactose malabsorption are not synonymous, and symptom perception may be influenced by the amount of lactose consumed, visceral sensitivity, intestinal microbiota, and coexisting functional gastrointestinal disorders [5]. This distinction is particularly important in IBS, since lactose intolerance appears to be more frequently reported in patients with IBS even though lactose maldigestion itself is not consistently more prevalent than in healthy individuals [6].

Lactose restriction may therefore represent a useful dietary strategy in selected physically active individuals, particularly those with confirmed lactose intolerance or a reproducible association between lactose consumption and gastrointestinal symptoms. However, routine elimination of dairy products in all athletes with gastrointestinal complaints may be unnecessary and potentially disadvantageous. Dairy products provide high-quality protein and important micronutrients, particularly calcium, and excessive long-term avoidance without appropriate dietary replacement may negatively affect nutritional adequacy and bone health [7]. Lactose-free dairy products may provide an alternative that maintains the nutritional value of conventional dairy while improving tolerance in susceptible individuals. Recent studies have also investigated lactose-free milk as a hydration and recovery beverage during or

after exercise, demonstrating its potential usefulness and generally acceptable gastrointestinal tolerance in physically active individuals [8-10].

Therefore, the relationship between lactose intake, gastrointestinal symptoms, and physical exercise requires an individualized approach that considers both symptom control and the nutritional requirements of the athlete. The present narrative review, entitled **“Lactose restriction and lactose-free dairy products in athletes with irritable bowel syndrome and exercise-associated gastrointestinal symptoms: implications for performance, hydration, and recovery,”** aims to evaluate the role of lactose restriction and lactose-free dairy products in physically active individuals with IBS or exercise-associated gastrointestinal symptoms. Particular attention is given to gastrointestinal tolerance, potential effects on training and sports performance, the use of lactose-free dairy products in hydration and post-exercise recovery, and the possible nutritional consequences of unnecessary long-term dairy restriction.

2. Materials and Methods

This review was based on studies published in the last 10 years and indexed in the PubMed database. The literature search focused on publications related to athletes, physical activity, exercise-associated gastrointestinal symptoms, irritable bowel syndrome (IBS), lactose intolerance, lactose malabsorption, and lactose-free dietary strategies. The following keywords were used: “athletes”, “sport”, “physical activity”, “exercise”, “endurance exercise”, “irritable bowel syndrome”, “IBS”, “exercise-associated gastrointestinal symptoms”, “lactose-free diet”, “lactose intolerance”, “lactose malabsorption”, “lactose-free milk”, “hydration”, “recovery”, and “sports nutrition”. Only articles published in English were included. The analysis covered original research articles, review papers, and relevant clinical or sports nutrition guidelines. Publications not directly related to the role of lactose restriction or lactose-free dairy products in physically active individuals, duplicate records, and studies published outside the defined time frame were excluded

3. Irritable bowel syndrome and gastrointestinal symptoms in physically active individuals

3.1. Irritable bowel syndrome in physically active individuals

Irritable bowel syndrome (IBS) is a disorder of gut–brain interaction characterized by recurrent abdominal pain associated with altered bowel habits. Its clinical manifestations include abdominal pain, bloating, diarrhea, constipation, urgency, and excessive gas

production. Although regular physical activity may have beneficial effects on gastrointestinal function and overall well-being in patients with IBS, prolonged or high-intensity exercise can also provoke gastrointestinal disturbances, particularly in susceptible individuals [11]. This creates a specific challenge in physically active individuals, in whom symptoms related to IBS may coexist with or be exacerbated by exercise-associated gastrointestinal symptoms.

The prevalence and clinical relevance of IBS among athletes have received increasing attention. In a study involving endurance athletes, the overall prevalence of medically diagnosed or Rome III-defined IBS was approximately 10%, while only a minority of affected athletes had previously received a medical diagnosis [3]. Athletes with IBS may experience symptoms both during daily activities and in association with exercise, making it difficult to distinguish between symptoms caused by the underlying disorder and those induced by exercise itself. This distinction is clinically important because therapeutic and nutritional approaches may differ depending on the predominant mechanism of symptom generation.

Strenuous exercise may temporarily alter gastrointestinal integrity and function through changes in splanchnic blood flow, gastrointestinal motility, epithelial permeability, and neuroendocrine responses [2,12]. These effects may increase susceptibility to abdominal discomfort, nausea, bloating, diarrhea, and urgency. Consequently, athletes with pre-existing gastrointestinal sensitivity, including IBS, may represent a population particularly vulnerable to exercise-associated symptoms. However, the available evidence specifically evaluating IBS in athletic populations remains limited, emphasizing the need for individualized assessment rather than assuming that gastrointestinal complaints during exercise are caused exclusively by IBS.

3.2. Impact of gastrointestinal symptoms on training and sports performance

Gastrointestinal symptoms can have a substantial impact on training quality and sports performance, particularly in endurance disciplines. Abdominal pain, nausea, diarrhea, urgency, and bloating may require athletes to reduce exercise intensity, interrupt training, modify planned routes, or stop competition altogether [12-13]. Gastrointestinal discomfort may also interfere with the consumption of carbohydrates and fluids during prolonged exercise, potentially limiting energy availability and hydration and thereby indirectly affecting exercise capacity and recovery [14].

The consequences of gastrointestinal symptoms extend beyond the acute episode. Athletes experiencing recurrent exercise-associated gastrointestinal complaints frequently introduce dietary changes, modify pre-exercise meals, restrict particular foods, or reduce food

intake before training and competition in an attempt to prevent symptoms [13]. Although such strategies may improve gastrointestinal comfort in selected individuals, poorly planned or excessive food restriction may compromise the ability to meet energy and nutrient requirements. Therefore, effective symptom management should aim not only to minimize gastrointestinal complaints but also to maintain adequate nutritional intake and support consistent training and recovery.

An additional consideration is the adaptability of the gastrointestinal tract to repeated nutritional exposure during exercise. The concept of “gut training” suggests that repeated intake of carbohydrates and fluids during training may improve gastrointestinal tolerance and nutrient absorption, potentially reducing symptom severity during competition [14]. This approach highlights the importance of integrating nutritional strategies into regular training rather than relying exclusively on dietary avoidance.

3.3. Diet-related gastrointestinal symptoms during exercise

Dietary intake is one of the major modifiable factors associated with gastrointestinal symptoms during physical activity. The amount, composition, and timing of food consumed before and during exercise may influence gastrointestinal tolerance. Large meals and foods containing high amounts of fat, fiber, protein, or poorly absorbed fermentable carbohydrates may increase gastrointestinal discomfort in susceptible athletes. For this reason, athletes frequently modify their dietary intake around training and competition, and foods containing fermentable oligosaccharides, disaccharides, monosaccharides, and polyols (FODMAPs) are among the products commonly restricted [4,15].

FODMAPs are poorly or variably absorbed carbohydrates that may increase intestinal water content and undergo fermentation by colonic bacteria, potentially contributing to luminal distension, gas production, bloating, abdominal pain, and altered bowel habits. Lactose belongs to this group of fermentable carbohydrates and may therefore contribute to symptoms in individuals with lactose malabsorption. Studies in endurance athletes have shown that FODMAP intake can be relatively high both habitually and around exercise and may be associated with gastrointestinal symptoms in susceptible individuals [15]. However, the relationship between dietary intake and exercise-associated symptoms is multifactorial, and the presence of symptoms after consuming a particular food does not necessarily indicate a specific food intolerance.

Short-term dietary modification may nevertheless be beneficial in selected athletes. A low-FODMAP dietary intervention has been associated with reductions in exercise-related

gastrointestinal symptoms and improved perceived ability to exercise in recreational runners [16]. Similar strategies have been investigated in endurance athletes with recurrent gastrointestinal symptoms, including individuals with diagnosed IBS [17]. These findings suggest that targeted reduction of fermentable carbohydrates may improve gastrointestinal tolerance in selected cases. However, highly restrictive dietary approaches should not be routinely applied to all athletes, particularly over prolonged periods. Identification of individual dietary triggers and adjustment of food intake according to training and competition demands appear to be more appropriate strategies. In this context, determining whether lactose specifically contributes to gastrointestinal symptoms is particularly relevant before recommending lactose restriction or complete dairy avoidance.

4. Lactose intolerance, IBS, and exercise-associated gastrointestinal symptoms

4.1. Lactose digestion, malabsorption, and individual tolerance

Lactose is a disaccharide composed of glucose and galactose and is naturally present in milk and dairy products. Its digestion occurs primarily in the small intestine through the activity of lactase, an enzyme located on the brush border of enterocytes. Reduced lactase activity may result in incomplete digestion and absorption of lactose, defined as lactose malabsorption. Undigested lactose reaches the colon, where bacterial fermentation and osmotic effects may lead to increased gas production, intestinal distension, abdominal pain, bloating, flatulence, and diarrhea [5,18].

It is important to distinguish lactose malabsorption from lactose intolerance. Lactose malabsorption refers to impaired digestion and absorption of lactose, whereas lactose intolerance describes the occurrence of gastrointestinal symptoms following lactose ingestion in an individual with lactose malabsorption [5,18]. The presence and severity of symptoms do not depend exclusively on lactase activity. They may also be influenced by the amount of lactose consumed, intestinal transit, gut microbiota composition, visceral sensitivity, and individual perception of gastrointestinal sensations [5,18]. Consequently, individuals with similar degrees of lactose malabsorption may experience markedly different clinical symptoms.

This individual variability is particularly relevant in physically active populations. Athletes frequently modify their dietary intake in response to gastrointestinal complaints, and lactose is among the fermentable carbohydrates most commonly avoided by those who associate specific foods with exercise-related gastrointestinal symptoms [4]. However,

gastrointestinal discomfort occurring after dairy consumption around exercise does not necessarily indicate lactose malabsorption. The timing and volume of food intake, exercise intensity, hydration status, and coexistence of functional gastrointestinal disorders may additionally influence symptom perception. Therefore, individual tolerance should be considered when evaluating the need for lactose restriction.

4.2. Overlap between lactose intolerance, IBS, and exercise-associated symptoms

Lactose intolerance, IBS, and exercise-associated gastrointestinal symptoms share several clinical manifestations, including abdominal pain, bloating, flatulence, diarrhea, and urgency. This substantial symptomatic overlap may make it difficult to determine the predominant cause of gastrointestinal complaints in physically active individuals. In particular, symptoms occurring after dairy consumption may be attributed to lactose intolerance even when they result from IBS-related visceral hypersensitivity or mechanisms associated with prolonged or intensive exercise.

The relationship between IBS and lactose intolerance is complex. A meta-analysis demonstrated that lactose intolerance was more frequent in patients with IBS than in healthy controls, whereas lactose maldigestion itself was not significantly more prevalent [6]. Similarly, studies evaluating IBS patients suggest that an increased perception of symptoms following lactose ingestion may occur despite comparable rates of objective lactose malabsorption [19-20]. These findings indicate that heightened visceral sensitivity and altered perception of intestinal distension may contribute to lactose-related complaints in IBS independently of the degree of lactase deficiency.

In athletes, this diagnostic overlap may be further complicated by exercise-associated gastrointestinal disturbances. Physical exertion may itself provoke abdominal discomfort, diarrhea, urgency, or bloating, particularly during endurance exercise. Therefore, symptoms experienced after lactose-containing foods before or during exercise should not automatically be attributed to lactose intolerance. Identification of a reproducible relationship between lactose consumption and symptoms, preferably also outside the exercise setting, may help distinguish true lactose-related symptoms from gastrointestinal complaints predominantly associated with IBS or physical exertion.

4.3. Self-reported versus objectively confirmed lactose intolerance

Self-reported lactose intolerance is common, but subjective perception of symptoms does not always correspond to objectively confirmed lactose malabsorption. This distinction is

particularly relevant in IBS, where abdominal symptoms may occur in response to multiple dietary and non-dietary factors. A recent systematic review evaluating self-perceived versus confirmed lactose intolerance in patients with IBS demonstrated considerable variability between self-reported symptoms and objective findings and concluded that subjective lactose intolerance may overestimate the presence of objectively confirmed lactose-related disorders [21].

A similar problem may occur in physically active populations. Athletes frequently exclude foods that they perceive as triggers of gastrointestinal symptoms, with lactose being one of the most commonly eliminated FODMAP components [4]. Although such self-directed dietary modification may provide symptomatic benefit in selected individuals, symptom improvement following elimination alone does not confirm lactose malabsorption. Unnecessary long-term restriction may also lead to avoidance of nutritionally valuable dairy products without a clear clinical indication.

When objective confirmation is clinically justified, hydrogen breath testing may be used to assess lactose malabsorption. Current European recommendations emphasize the importance of evaluating both carbohydrate malabsorption and the occurrence of symptoms during testing, since an abnormal breath test alone does not necessarily establish clinically relevant lactose intolerance [22]. Therefore, the decision to introduce lactose restriction in athletes with IBS or exercise-associated gastrointestinal symptoms should combine dietary history, reproducibility of symptoms, individual tolerance, and, when appropriate, objective diagnostic assessment rather than relying solely on self-reported intolerance.

5. Exercise-associated gastrointestinal symptoms in athletes

5.1. Definition and clinical presentation

Exercise-associated gastrointestinal symptoms (Ex-GIS) refer to gastrointestinal complaints that occur during or shortly after physical exercise. They are particularly common in endurance sports, where prolonged exercise places considerable physiological and nutritional demands on the gastrointestinal tract [12,23]. Ex-GIS may involve both the upper and lower gastrointestinal tract. Upper gastrointestinal symptoms include nausea, vomiting, reflux, belching, epigastric discomfort, and early satiety, whereas lower gastrointestinal symptoms commonly include abdominal cramping, bloating, flatulence, diarrhea, loose stools, and an urgent need to defecate [12-13].

The severity of Ex-GIS varies considerably between individuals and may range from mild transient discomfort to symptoms severe enough to reduce exercise intensity or interrupt competition. In most cases, symptoms are reversible after exercise; however, severe gastrointestinal disturbances, including gastrointestinal bleeding or marked diarrhea, may occasionally occur during prolonged and strenuous exercise [12,23]. Importantly, Ex-GIS should be distinguished from chronic gastrointestinal disorders such as IBS, although both conditions may coexist and share similar clinical manifestations.

5.2. Physiological mechanisms

The pathophysiology of Ex-GIS is multifactorial and is commonly described within the concept of exercise-induced gastrointestinal syndrome (EIGS). Two major physiological pathways are involved: reduced splanchnic blood flow and increased sympathetic nervous system activity during exercise [12,23]. During prolonged or intensive physical activity, blood flow is redistributed from the gastrointestinal tract toward working skeletal muscles, the heart, and the skin. This reduction in gastrointestinal perfusion may contribute to intestinal epithelial injury, increased intestinal permeability, and impaired gastrointestinal function [12,23].

Changes in gastrointestinal motility, gastric emptying, digestion, and nutrient absorption may additionally contribute to symptom development. The magnitude of gastrointestinal disturbances generally increases with increasing exercise stress and may be further enhanced by environmental heat and dehydration [23]. Exercise performed in hot conditions may intensify splanchnic hypoperfusion and thermal strain, increasing the risk of intestinal damage and gastrointestinal symptoms. Experimental evidence also suggests that exercise modality may influence gastrointestinal responses, although the relationship between running, cycling, and symptom severity is complex and dependent on exercise conditions [24].

5.3. Mechanical and nutritional mechanisms

Mechanical factors may also contribute to gastrointestinal symptoms during exercise. Repetitive impact and abdominal movement during running may increase gastrointestinal discomfort, while body position during cycling may influence upper gastrointestinal symptoms such as reflux or abdominal pressure. However, mechanical stress alone does not explain the occurrence of Ex-GIS, and symptoms usually result from interactions between physiological, mechanical, and nutritional factors [12,24].

Nutritional intake before and during exercise is another important determinant of gastrointestinal tolerance. Large meals consumed shortly before exercise, excessive intake of

fat, protein, or fiber, highly concentrated carbohydrate solutions, and excessive or inadequate fluid intake may increase gastrointestinal discomfort [13,25]. Fermentable carbohydrates may also contribute to symptoms through osmotic effects and intestinal fermentation in susceptible athletes. Lactose may therefore represent a potential dietary trigger in individuals with lactose malabsorption, particularly when consumed in larger quantities before exercise.

At the same time, insufficient nutritional intake is not an optimal strategy for preventing gastrointestinal symptoms. Restricting carbohydrate or fluid intake during prolonged exercise may compromise energy availability, hydration, and performance. Repeated exposure to carbohydrate and fluid intake during training, often referred to as “gut training”, may improve gastrointestinal tolerance and reduce symptoms in some athletes [14,26]. Therefore, nutritional strategies should focus on identifying individual triggers while maintaining adequate energy and fluid availability rather than broadly eliminating multiple food groups.

5.4. Risk factors and susceptible groups

The risk of Ex-GIS is influenced by both extrinsic and intrinsic factors. Exercise-related factors include prolonged duration, high exercise intensity, environmental heat, dehydration, and demanding competition conditions [12,23]. Ultra-endurance and endurance athletes may be particularly susceptible because of the prolonged physiological stress and the need to consume substantial amounts of carbohydrates and fluids during exercise. Athletes who already experience gastrointestinal symptoms during training may also be more likely to report symptoms during competition.

Individual susceptibility is equally important. Previous gastrointestinal disorders, including IBS, increased visceral sensitivity, anxiety, previous episodes of Ex-GIS, and poor tolerance of food or fluids during exercise may increase symptom risk [3,12-13]. Nutritional habits are also relevant, as athletes who introduce unfamiliar foods, supplements, or high carbohydrate loads during competition without previous testing may experience more pronounced gastrointestinal discomfort.

Environmental and behavioral factors may further modify risk. Heat exposure, hypohydration, competition-related stress, and inappropriate timing or composition of pre-exercise meals have all been associated with gastrointestinal symptoms [23,25]. Therefore, Ex-GIS should be considered the result of multiple interacting mechanisms rather than a single pathological process. Identification of individual risk factors and testing nutritional strategies during regular training are essential components of symptom prevention, particularly in athletes with IBS, suspected lactose intolerance, or recurrent gastrointestinal complaints.

6. Lactose restriction in athletes

6.1. Athletes with confirmed lactose intolerance

Lactose restriction may be beneficial in athletes with objectively confirmed lactose intolerance, particularly when gastrointestinal symptoms occur reproducibly after the consumption of lactose-containing foods. The severity of symptoms depends not only on the degree of lactose malabsorption but also on the amount of lactose consumed, individual visceral sensitivity, intestinal transit, and the composition of the meal [5,18]. Therefore, complete elimination of lactose is not always necessary, as some individuals may tolerate small amounts of lactose without clinically relevant symptoms.

In physically active individuals, the decision to restrict lactose should additionally consider the timing of dairy consumption in relation to exercise. Gastrointestinal complaints experienced after a pre-exercise meal may result from several interacting factors and should not automatically be attributed to lactose intolerance. When symptoms are persistent and clearly associated with lactose intake, hydrogen breath testing combined with symptom assessment may help confirm clinically relevant lactose intolerance [22]. A targeted reduction of lactose, rather than complete avoidance of all dairy products, may therefore represent a more appropriate strategy for athletes with confirmed intolerance.

6.2. Athletes with irritable bowel syndrome

Athletes with IBS may be particularly likely to modify their diet in response to gastrointestinal symptoms. Among runners with gastrointestinal disorders, individuals with IBS or inflammatory bowel disease reported a high prevalence of exercise-related gastrointestinal symptoms and frequently avoided milk products before competition [27]. However, avoidance of dairy does not necessarily indicate that lactose is the primary cause of symptoms.

The relationship between IBS and lactose intolerance remains complex because patients with IBS may report lactose-related symptoms even in the absence of objectively increased lactose maldigestion [6]. Increased visceral sensitivity, altered gut–brain interaction, and sensitivity to other fermentable carbohydrates may contribute to symptom development. Consequently, isolated lactose restriction is most likely to be useful when a reproducible association between lactose consumption and symptoms can be demonstrated. In athletes with IBS and multiple dietary triggers, a broader but temporary dietary strategy, such as FODMAP modification, may be more appropriate than focusing exclusively on lactose [17,28].

6.3. Athletes with exercise-associated gastrointestinal symptoms

Exercise-associated gastrointestinal symptoms are frequently managed by athletes through self-directed dietary restriction. Lactose-containing foods appear to be among the products commonly avoided by athletes who perceive FODMAP-containing foods as gastrointestinal triggers [4]. Similarly, runners with gastrointestinal disorders frequently report avoidance of milk products before competition [27]. Nevertheless, current evidence does not establish that lactose restriction alone prevents Ex-GIS in athletes without confirmed lactose intolerance.

Symptoms occurring during exercise may be caused by physiological, mechanical, and nutritional factors independent of lactose digestion. Therefore, dietary restriction should be based on an identifiable relationship between lactose intake and symptoms rather than introduced routinely in all athletes with Ex-GIS. Short-term modification of fermentable carbohydrate intake may be useful in athletes with recurrent symptoms, but individual responses vary considerably [16,28]. In practice, athletes may benefit from testing different lactose-containing and lactose-free foods during training before applying dietary restrictions during competition.

6.4. Lactose restriction versus low-FODMAP strategies

Lactose is one component of the FODMAP group, which also includes fructose, fructans, galacto-oligosaccharides, and polyols. Therefore, isolated lactose restriction represents a narrower dietary intervention than the low-FODMAP approach. This may be advantageous in athletes with confirmed lactose intolerance because it limits unnecessary dietary restriction while allowing other carbohydrate sources to remain in the diet.

In athletes with broader exercise-associated gastrointestinal symptoms, however, evidence supporting short-term low-FODMAP interventions is stronger than evidence for isolated lactose restriction. Studies in runners have demonstrated that short-term reduction of dietary FODMAP intake may decrease gastrointestinal symptoms and improve perceived exercise tolerance [16,28]. More recent research in endurance athletes also suggests that a high-carbohydrate diet with reduced FODMAP content may decrease gastrointestinal symptoms before and during prolonged exercise compared with a high-FODMAP diet, although improvements in gastrointestinal symptoms do not necessarily translate into better objective performance [29]. A recent systematic review similarly concluded that low-FODMAP

strategies may be useful in the prevention of gastrointestinal symptoms in endurance athletes, although the available evidence remains limited and heterogeneous [30].

Therefore, lactose restriction and low-FODMAP strategies should not be considered interchangeable. Lactose restriction may be preferable when lactose has been identified as a specific dietary trigger, whereas a short-term low-FODMAP approach may be considered in athletes with multiple food-related gastrointestinal symptoms or persistent Ex-GIS. In both cases, long-term unnecessary restriction should be avoided, and dietary interventions should be individualized according to gastrointestinal tolerance, training demands, and overall nutritional requirements.

7. Lactose-free dairy products in sports nutrition

7.1. Pre-exercise nutrition

Pre-exercise nutrition should provide adequate energy and nutrients while minimizing the risk of gastrointestinal discomfort. Dairy products may contribute carbohydrates, high-quality protein, fluids, and micronutrients; however, athletes who experience lactose-related symptoms may avoid milk and other dairy products before training or competition. In individuals with confirmed lactose intolerance, lactose-free dairy products may provide a practical alternative because lactose hydrolysis improves tolerance while maintaining the nutritional value of conventional dairy products.

Evidence specifically evaluating lactose-free dairy products as pre-exercise meals or beverages remains limited. Therefore, their use before exercise should be individualized according to gastrointestinal tolerance, portion size, timing of intake, and exercise intensity. Athletes with a history of gastrointestinal symptoms should test lactose-free products during regular training rather than introduce unfamiliar foods immediately before competition. Importantly, replacing conventional dairy with lactose-free alternatives may be preferable to complete dairy avoidance when lactose is the primary suspected trigger.

7.2. Gastrointestinal tolerance during exercise

Gastrointestinal tolerance is an important consideration when dairy products are consumed close to or during exercise. Milk contains protein, carbohydrate, and electrolytes, but its composition and relatively high nutrient density may affect gastric comfort when consumed in large quantities during prolonged exercise. In athletes with lactose intolerance, the presence of lactose may represent an additional factor contributing to abdominal discomfort, bloating, or diarrhea.

Direct evidence concerning lactose-free milk during exercise is emerging. Aragón-Vargas et al. evaluated voluntary consumption of skimmed lactose-free milk during 90 minutes of moderate-intensity exercise in the heat. Although participants consumed less milk than water, lactose-free milk effectively maintained hydration status. Some gastrointestinal sensations, including belching, thick saliva, and abdominal discomfort, were reported more frequently with milk, but their overall intensity remained low [9]. These results suggest that lactose-free milk can be tolerated during moderate exercise in selected physically active individuals, although it may not be optimal as a universal replacement for water or conventional sports drinks during high-intensity or prolonged competition.

The gastrointestinal response to milk-based beverages also appears to depend on their nutritional composition and the amount consumed. Studies evaluating dairy-based recovery beverages indicate that substantial carbohydrate and protein intake after strenuous exercise can be tolerated without clinically significant gastrointestinal disturbances in many athletes [32-33]. However, individual tolerance remains important, particularly in athletes with IBS, previous Ex-GIS, or suspected food intolerance.

7.3. Post-exercise hydration

Post-exercise rehydration aims to replace fluid and electrolyte losses resulting from sweating and to restore fluid balance before subsequent training or competition. Milk has several characteristics that may support this process, including a high water content and the presence of sodium, potassium, carbohydrate, and protein [31]. These properties may promote fluid retention and simultaneously provide nutrients required for post-exercise recovery.

Recent evidence directly supports the potential role of lactose-free milk in post-exercise rehydration. In a randomized study of physically active individuals who lost approximately 2% of body mass during cycling in the heat, skimmed lactose-free milk resulted in greater fluid retention than water during the three-hour recovery period. Gastrointestinal symptoms were generally mild and were not significantly different between lactose-free milk, water, and a sports drink [10]. These findings indicate that lactose-free milk may represent an effective post-exercise rehydration option for physically active individuals, including those wishing to avoid lactose.

The potential advantage of lactose-free milk is particularly relevant because removal of lactose does not require elimination of the remaining nutritional components of dairy products. Therefore, athletes with lactose intolerance may potentially benefit from the hydration properties of milk without exposure to the lactose responsible for their gastrointestinal

symptoms. Nevertheless, the currently available evidence is based on relatively small studies, and further research in competitive athletes and different exercise conditions is required before broad recommendations can be established.

7.4. Muscle recovery and glycogen restoration

Post-exercise nutritional recovery involves restoration of muscle glycogen, stimulation of muscle protein synthesis, replacement of fluids and electrolytes, and support of tissue repair. Cow's milk naturally provides both carbohydrate and high-quality proteins, including whey and casein, and has therefore been investigated as a post-exercise recovery beverage [31]. Evidence from studies using conventional milk and chocolate milk suggests that milk-based beverages can support several aspects of recovery and may provide outcomes comparable to commonly used carbohydrate or carbohydrate-protein recovery beverages [31,35].

The combination of carbohydrate and protein may be particularly useful when rapid recovery is required between exercise sessions. Studies examining milk-based beverages have demonstrated potential benefits for subsequent exercise capacity and several markers of recovery [33-34]. Chocolate milk has also been extensively investigated because its additional carbohydrate content provides a carbohydrate-to-protein combination suitable for post-exercise nutrition. A systematic review and meta-analysis concluded that chocolate milk generally produced similar or, for selected outcomes, potentially favorable recovery responses compared with other recovery beverages, although the available evidence was limited by relatively small and heterogeneous studies [35].

Evidence specifically concerning lactose-free dairy products is considerably more limited. A low-fat, lactose-free, leucine-enriched chocolate milk beverage has been evaluated following exhaustive exercise and demonstrated acceptable sensory characteristics and gastrointestinal tolerance [8]. However, current evidence is insufficient to conclude that removal of lactose itself enhances muscle recovery or glycogen restoration. The principal potential advantage of lactose-free dairy products is therefore improved gastrointestinal tolerance in lactose-intolerant athletes while preserving dairy-derived protein, carbohydrate, fluids, and micronutrients. Lactose-free products should consequently be considered an alternative means of delivering recovery nutrition rather than a recovery strategy with proven physiological superiority over conventional dairy products.

8. Nutritional risks of dairy restriction in athletes

8.1. Energy and protein intake

Athletes have increased nutritional requirements related to training, recovery, and adaptation to exercise. Adequate energy and protein intake is particularly important for maintaining muscle mass, supporting muscle protein synthesis, and facilitating recovery between training sessions [36]. Dairy products represent a convenient source of high-quality protein containing all essential amino acids, as well as carbohydrates and several micronutrients. Consequently, unnecessary elimination of dairy products may reduce dietary variety and remove a useful source of nutrients from an athlete's diet [31,36].

Importantly, lactose restriction does not require complete dairy avoidance. Lactose-free milk and other lactose-free dairy products retain the protein content and most of the nutritional characteristics of conventional dairy products while eliminating or substantially reducing lactose. Therefore, in athletes with lactose intolerance, replacing conventional dairy with lactose-free products may be nutritionally preferable to eliminating the entire food group. Particular attention should be given to athletes who replace dairy products with plant-based beverages, as many of these products contain substantially less protein than cow's milk [39-40].

8.2. Calcium, vitamin D, and bone health

Bone health is an important consideration in athletes because skeletal tissue is continuously exposed to mechanical loading and must adapt to training demands. Adequate energy availability, calcium intake, vitamin D status, and protein intake are among the nutritional factors contributing to the maintenance of healthy bones [7,37]. Dairy products are an important dietary source of calcium and high-quality protein, and their unnecessary long-term elimination without appropriate replacement may increase the risk of inadequate intake of nutrients relevant to bone health.

Athletes may be particularly vulnerable to impaired bone health when restrictive dietary practices coexist with high training loads or low energy availability. Insufficient calcium intake and inadequate vitamin D status may further compromise skeletal health and may be particularly relevant in athletes at risk of bone stress injuries [37-38]. Therefore, athletes restricting dairy should ensure adequate calcium intake from lactose-free dairy products, fortified alternatives, or other calcium-rich foods. Vitamin D intake and status should also be

considered independently, as dietary availability varies and vitamin D requirements cannot necessarily be met through dairy consumption alone.

In athletes with lactose intolerance, lactose-free dairy products may provide a particularly practical strategy because they allow continued consumption of calcium- and protein-rich dairy foods without exposure to the lactose responsible for symptoms. Thus, dietary counselling should distinguish between the need to restrict lactose and the unnecessary elimination of all dairy products.

8.3. Low energy availability and restrictive eating behaviours

Low energy availability (LEA) occurs when dietary energy intake is insufficient to support the physiological functions of the body after accounting for the energy expended during exercise. Persistent or problematic LEA may contribute to Relative Energy Deficiency in Sport (REDs), a syndrome associated with adverse health and performance consequences in both female and male athletes [38]. Gastrointestinal symptoms may complicate this issue because athletes experiencing recurrent symptoms frequently modify or restrict their food intake in an attempt to improve gastrointestinal comfort.

Dairy avoidance alone should not be considered a direct cause of LEA or REDs. However, unnecessary dairy elimination may contribute to an increasingly restrictive dietary pattern, particularly when combined with avoidance of other foods such as gluten-containing products, high-FODMAP foods, fiber-rich foods, or selected carbohydrate sources. In athletes with IBS or Ex-GIS, multiple simultaneous dietary restrictions may reduce overall energy intake, food variety, and the ability to meet nutritional requirements.

Therefore, dietary restriction used to control gastrointestinal symptoms should be as targeted as possible. Athletes should avoid eliminating entire food groups without clear clinical or nutritional justification, and restrictive interventions should ideally be followed by systematic reintroduction according to individual tolerance. This approach may help balance gastrointestinal symptom management with adequate energy availability and long-term nutritional health.

8.4. Nutritionally adequate dairy alternatives

When conventional dairy products are poorly tolerated, lactose-free dairy products represent the most direct nutritional alternative for individuals in whom lactose is the primary gastrointestinal trigger. They provide dairy-derived protein, calcium, and other nutrients while

avoiding or markedly reducing lactose exposure. For this reason, lactose-free dairy products may be preferable to complete dairy avoidance in athletes with confirmed lactose intolerance.

Plant-based beverages may also be used as dairy alternatives, but their nutritional composition varies substantially according to the source ingredient and degree of fortification [39-40]. Compared with cow's milk, many plant-based beverages contain lower amounts of protein and may differ in protein quality, calcium, vitamin D, vitamin B12, iodine, and other micronutrients [39-40]. Soy-based beverages generally provide a protein content closer to that of cow's milk than many almond, rice, coconut, or oat-based alternatives, although individual products vary considerably [39-40].

Athletes choosing plant-based alternatives should therefore evaluate nutritional labels rather than assuming that all dairy substitutes are nutritionally equivalent. Preference should be given to products providing adequate protein and fortified with nutrients such as calcium and vitamin D when these nutrients are not sufficiently supplied elsewhere in the diet. The choice of substitute should also consider total energy intake, gastrointestinal tolerance, training demands, and the athlete's overall dietary pattern. In athletes restricting lactose rather than dairy for ethical or other reasons, lactose-free dairy products remain a simple strategy for maintaining the nutritional benefits of conventional dairy while minimizing lactose-related gastrointestinal symptoms.

9. Practical recommendations

9.1. When should lactose restriction be considered?

Lactose restriction should mainly be considered in athletes with confirmed lactose intolerance or a clear and reproducible relationship between lactose intake and gastrointestinal symptoms. Because abdominal pain, bloating, diarrhea, and urgency may also result from IBS or exercise-associated gastrointestinal symptoms, lactose should not be routinely eliminated in all athletes with gastrointestinal complaints [5,18]. When the relationship between lactose consumption and symptoms is uncertain, hydrogen breath testing combined with symptom assessment may support diagnosis [22].

9.2. Timing of lactose intake around training and competition

The amount and timing of lactose consumption may influence gastrointestinal tolerance. Athletes with suspected lactose-related symptoms should test lactose-containing foods during regular training rather than immediately before competition. If conventional dairy repeatedly provokes symptoms before prolonged or intensive exercise, lactose-free alternatives

may be considered. Individual tolerance should remain the main criterion, as some athletes may tolerate small amounts of lactose without relevant symptoms [5,18].

9.3. Elimination and reintroduction protocol

A short-term lactose-restricted diet may be used as a diagnostic and therapeutic trial in athletes with suspected lactose-related symptoms. During this period, symptom frequency and severity should be monitored during both daily activities and exercise. If symptoms improve, lactose-containing foods should be gradually reintroduced to determine the individual tolerance threshold. Complete long-term dairy avoidance should generally be avoided unless clearly justified, because lactose restriction does not require elimination of all dairy products [5,18].

9.4. Role of the physician and sports dietitian

Management should ideally involve cooperation between the physician and sports dietitian. The physician can evaluate persistent or atypical symptoms, exclude organic gastrointestinal disease, and determine whether additional diagnostic testing is required [22]. The sports dietitian can help adapt lactose restriction to training demands while maintaining adequate energy, protein, calcium, and vitamin D intake. This approach may also reduce the risk of unnecessary multiple food restrictions and low energy availability [36-38].

10. Discussion

The present review highlights the complex relationship between lactose intake, irritable bowel syndrome, and exercise-associated gastrointestinal symptoms in physically active individuals. Gastrointestinal complaints are common among athletes, particularly in endurance disciplines, but their presence does not necessarily indicate lactose intolerance or IBS. Exercise itself may provoke gastrointestinal symptoms through physiological, mechanical, and nutritional mechanisms, including reduced splanchnic blood flow, altered gastrointestinal motility, dehydration, heat stress, and inappropriate food or fluid intake [12,23-26]. Therefore, symptoms occurring after dairy consumption around exercise should be interpreted within a broader clinical and nutritional context.

An important finding is that lactose intolerance, lactose malabsorption, and self-reported dairy sensitivity should not be considered equivalent conditions. Patients with IBS may report lactose-related symptoms more frequently than healthy individuals despite a similar prevalence of objective lactose maldigestion [6]. This discrepancy may partly result from visceral hypersensitivity and altered perception of intestinal distension [5,18-21]. A similar

situation may occur in athletes, who frequently eliminate lactose-containing foods based on perceived gastrointestinal effects without objective confirmation of intolerance [4,27]. Consequently, routine lactose restriction in all athletes with gastrointestinal symptoms cannot be supported by the currently available evidence.

The potential benefits of lactose restriction appear most relevant in athletes with confirmed lactose intolerance or a clear and reproducible relationship between lactose consumption and symptoms. In such individuals, reducing lactose intake may improve gastrointestinal comfort and facilitate training or competition. However, evidence directly investigating isolated lactose restriction in athletes remains limited. In contrast, low-FODMAP dietary strategies have been studied more extensively and may reduce exercise-associated gastrointestinal symptoms in selected athletes [16-17,28-30]. Since lactose represents only one component of the FODMAP group, broader fermentable carbohydrate restriction may be more appropriate in athletes with multiple dietary triggers, whereas isolated lactose restriction may be sufficient when lactose has been identified as the predominant trigger.

Another relevant aspect is that lactose restriction does not require complete elimination of dairy products. Lactose-free dairy products may allow athletes with lactose intolerance to maintain the nutritional advantages of milk and dairy while reducing exposure to lactose. Available studies suggest that lactose-free milk can be tolerated during exercise and may support post-exercise rehydration [9-10]. Dairy-based recovery beverages also provide high-quality protein, carbohydrates, fluids, and electrolytes that may contribute to post-exercise recovery [31-35]. Nevertheless, evidence specifically demonstrating superior recovery or performance outcomes from lactose-free compared with conventional dairy products is currently insufficient. Their main advantage therefore appears to be improved accessibility of dairy-based nutrition for athletes who poorly tolerate lactose.

The nutritional consequences of unnecessary dairy avoidance should also be considered. Athletes have increased requirements for energy, protein, and selected micronutrients, and dairy products may contribute substantially to protein and calcium intake [31,36-37]. Excessive restriction, particularly when combined with avoidance of other food groups, may reduce dietary variety and contribute to inadequate nutrient intake or low energy availability [38]. This issue is particularly relevant in athletes who already modify their diet because of IBS or recurrent gastrointestinal complaints. Lactose-free dairy products or appropriately fortified alternatives may help maintain nutritional adequacy while allowing gastrointestinal symptoms to be managed [39-40].

From a practical perspective, dietary recommendations should therefore be individualized. Athletes with suspected lactose-related symptoms may benefit from a structured assessment including dietary history, symptom monitoring, short-term lactose restriction, and subsequent reintroduction. When clinically appropriate, hydrogen breath testing may support objective assessment [22]. Importantly, dietary strategies should be tested during training rather than introduced for the first time immediately before competition. Cooperation between physicians and sports dietitians may help distinguish gastrointestinal disease from exercise-related symptoms, minimize unnecessary dietary restriction, and maintain adequate nutrition.

Several limitations should be acknowledged. First, the number of studies directly evaluating lactose restriction or lactose-free dairy products in athletic populations is small. Second, available studies differ substantially in exercise modality, training status, dietary intervention, symptom assessment, and study duration, which limits direct comparison. Third, much of the evidence concerning lactose intolerance is derived from general or IBS populations rather than competitive athletes. Finally, many studies evaluating dietary strategies in athletes focus on broader FODMAP restriction rather than lactose alone. Future research should therefore include well-designed randomized studies evaluating isolated lactose restriction, lactose-free dairy products, gastrointestinal tolerance, and performance outcomes in different athletic populations, particularly athletes with confirmed lactose intolerance or IBS.

12. Conclusions

Lactose restriction may be a useful dietary strategy in selected physically active individuals, particularly athletes with confirmed lactose intolerance or a reproducible association between lactose consumption and gastrointestinal symptoms. However, gastrointestinal complaints during exercise are multifactorial and may result from IBS, exercise-associated gastrointestinal disturbances, other dietary components, or interactions between these factors. Therefore, routine lactose elimination in all athletes with gastrointestinal symptoms is not supported by current evidence.

Lactose-free dairy products may provide a practical alternative to conventional dairy by maintaining high-quality protein, calcium, fluids, and other nutrients while reducing the risk of lactose-related symptoms. Dietary management should remain individualized, with unnecessary long-term dairy restriction avoided whenever possible. Further studies specifically involving athletes are required to determine whether lactose restriction or lactose-free dairy

products can improve gastrointestinal tolerance, training consistency, recovery, hydration, or sports performance.

Disclosure

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Visualization, Natalia Dziuba, Joanna Mioduszevska and Aleksandra Sim; supervision, Zofia Roguska and Andrzej Zuzak;

Project administration Andrzej Zuzak.

All authors have read and agreed with the published version of the manuscript.

Funding statement:

No external funding was received to perform this review

Institutional Review Board Statement:

Not applicable

Informed Consent Statement:

Not applicable

Data Availability Statement:

Not applicable

Conflict of Interest Statement:

The authors declare no conflict of interest.

Declaration of the use of generative AI and AI-assisted technologies in the writing process.

In preparing this work, the author(s) used CHAT GPT 5.4 for the purpose of linguistic correctness and context. After using this tool/service, the author(s) have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

References

- [1] de Oliveira EP, Burini RC, Jeukendrup A. Gastrointestinal complaints during exercise: prevalence, etiology, and nutritional recommendations. *Sports Med.* 2014;44(Suppl 1). doi:10.1007/s40279-014-0153-2.
- [2] Costa RJS, Snipe RMJ, Kitic CM, Gibson PR. Systematic review: exercise-induced gastrointestinal syndrome—implications for health and intestinal disease. *Aliment Pharmacol Ther.* 2017;46(3):246-265. doi:10.1111/apt.14157.
- [3] Killian LA, Lee SY. Irritable bowel syndrome is underdiagnosed and ineffectively managed among endurance athletes. *Appl Physiol Nutr Metab.* 2019;44(12):1329-1338. doi:10.1139/apnm-2019-0261.
- [4] Lis DM, Ahuja KDK, Stellingwerff T, Kitic CM, Fell JW. Food avoidance in athletes: FODMAP foods on the list. *Appl Physiol Nutr Metab.* 2016;41(9):1002-1004. doi:10.1139/apnm-2015-0428.
- [5] Misselwitz B, Butter M, Verbeke K, Fox MR. Update on lactose malabsorption and intolerance: pathogenesis, diagnosis and clinical management. *Gut.* 2019;68(11):2080-2091. doi:10.1136/gutjnl-2019-318404.
- [6] Varjú P, Gede N, Szakács Z, et al. Lactose intolerance but not lactose maldigestion is more frequent in patients with irritable bowel syndrome than in healthy controls: a meta-analysis. *Neurogastroenterol Motil.* 2019;31(5). doi:10.1111/nmo.13527.
- [7] Hodges JK, Cao S, Cladis DP, Weaver CM. Lactose intolerance and bone health: the challenge of ensuring adequate calcium intake. *Nutrients.* 2019;11(4):718. doi:10.3390/nu11040718.
- [8] da Silva CD, de Oliveira DR, Perrone ÍT, Fonseca CH, Garcia ES. Low-fat, lactose-free and leucine-enriched chocolate cow milk prototype: a preliminary study on sensorial

- acceptability and gastrointestinal complaints following exhaustive exercise. *J Int Soc Sports Nutr.* 2021;18(1):14. doi:10.1186/s12970-020-00406-0.
- [9] Aragón-Vargas LF, Garzón-Mosquera JC, Montoya-Arroyo JA. Voluntary hydration with skimmed lactose-free milk during exercise in the heat: exploring effectiveness and tolerance. *Nutrients.* 2023;15(9):2069. doi:10.3390/nu15092069.
- [10] Aragón-Vargas LF, Garzón-Mosquera JC, Montoya-Arroyo JA. Skimmed, lactose-free milk ingestion postexercise: rehydration effectiveness and gastrointestinal disturbances versus water and a sports drink in physically active people. *Int J Sport Nutr Exerc Metab.* 2024;34(5):258-266. doi:10.1123/ijsnem.2023-0253.
- [11] Zhou C, Zhao E, Li Y, Jia Y, Li F. Exercise therapy of patients with irritable bowel syndrome: A systematic review of randomized controlled trials. *Neurogastroenterol Motil.* 2019;31(2). doi:10.1111/nmo.13461.
- [12] Costa RJS, Young P, Gill SK, Snipe RMJ, Gaskell S, Russo I, Burke LM. Assessment of exercise-associated gastrointestinal perturbations in research and practical settings: methodological concerns and recommendations for best practice. *Int J Sport Nutr Exerc Metab.* 2022;32(5):387-418. doi:10.1123/ijsnem.2022-0048.
- [13] Scrivin R, Costa RJS, Pelly F, Lis D, Slater G. An exploratory study of the management strategies reported by endurance athletes with exercise-associated gastrointestinal symptoms. *Front Nutr.* 2022;9:1003445. doi:10.3389/fnut.2022.1003445.
- [14] Jeukendrup AE. Training the gut for athletes. *Sports Med.* 2017;47(Suppl 1):101-110. doi:10.1007/s40279-017-0690-6.
- [15] Killian LA, Muir JG, Barrett JS, Burd NA, Lee SY. High fermentable oligosaccharides, disaccharides, monosaccharides, and polyols (FODMAP) consumption among endurance athletes and relationship to gastrointestinal symptoms. *Front Nutr.* 2021;8:637160. doi:10.3389/fnut.2021.637160.
- [16] Wiffin M, Smith L, Antonio J, Johnstone J, Beasley L, Roberts J. Effect of a short-term low fermentable oligosaccharide, disaccharide, monosaccharide and polyol (FODMAP) diet on exercise-related gastrointestinal symptoms. *J Int Soc Sports Nutr.* 2019;16:1. doi:10.1186/s12970-019-0268-9.
- [17] Gaskell SK, Costa RJS. Applying a low-FODMAP dietary intervention to a female ultraendurance runner with irritable bowel syndrome during a multistage ultramarathon. *Int J Sport Nutr Exerc Metab.* 2019;29(1):61-67. doi:10.1123/ijsnem.2017-0398.
- [18] Usai-Satta P, Lai M, Oppia F. Lactose malabsorption and presumed related disorders: A review of current evidence. *Nutrients.* 2022;14(3):584. doi:10.3390/nu14030584.

- [19] Xiong L, Wang Y, Gong X, Chen M. Prevalence of lactose intolerance in patients with diarrhea-predominant irritable bowel syndrome: Data from a tertiary center in southern China. *J Health Popul Nutr.* 2017;36(1):38. doi:10.1186/s41043-017-0113-1.
- [20] Bouchoucha M, Fysekidis M, Romptaux P, Raynaud JJ, Sabate JM, Benamouzig R. Lactose sensitivity and lactose malabsorption: The 2 faces of lactose intolerance. *J Neurogastroenterol Motil.* 2021;27(2):257-264. doi:10.5056/jnm20094.
- [21] Pop A, Popa SL, Pop DD, Ismaiel A, Nechita VI, Dumitrascu DL. Self-perceived lactose intolerance versus confirmed lactose intolerance in irritable bowel syndrome: A systematic review. *J Gastrointestin Liver Dis.* 2025;34(1):90-97. doi:10.15403/jgld-5836.
- [22] Hammer HF, Fox MR, Keller J, et al. European guideline on indications, performance, and clinical impact of hydrogen and methane breath tests in adult and pediatric patients: European Association for Gastroenterology, Endoscopy and Nutrition, European Society of Neurogastroenterology and Motility, and European Society for Paediatric Gastroenterology Hepatology and Nutrition consensus. *United European Gastroenterol J.* 2022;10(1):15-40. doi:10.1002/ueg2.12133.
- [23] Costa RJS, Gaskell SK, McCubbin AJ, Snipe RMJ. Exertional-heat stress-associated gastrointestinal perturbations during Olympic sports: Management strategies for athletes preparing and competing in the 2020 Tokyo Olympic Games. *Temperature (Austin).* 2020;7(1):58-88. doi:10.1080/23328940.2019.1597676.
- [24] Costa RJS, Mika AS, McCubbin AJ. The impact of exercise modality on exercise-induced gastrointestinal syndrome and associated gastrointestinal symptoms. *J Sci Med Sport.* 2022;25(10):788-793. doi:10.1016/j.jsams.2022.07.003.
- [25] Wilson PB. “I think I’m gonna hurl”: A narrative review of the causes of nausea and vomiting in sport. *Sports (Basel).* 2019;7(7):162. doi:10.3390/sports7070162.
- [26] Martinez IG, Mika AS, Biesiekierski JR, Costa RJS. The effect of gut-training and feeding-challenge on markers of gastrointestinal status in response to endurance exercise: A systematic literature review. *Sports Med.* 2023;53(6):1175-1200. doi:10.1007/s40279-023-01841-0.
- [27] Erdman KA, Jones KW, Madden RF, Gammack N, Parnell JA. Dietary patterns in runners with gastrointestinal disorders. *Nutrients.* 2021;13(2):448. doi:10.3390/nu13020448.
- [28] Lis DM, Stellingwerff T, Kitic CM, Fell JW, Ahuja KDK. Low FODMAP: A preliminary strategy to reduce gastrointestinal distress in athletes. *Med Sci Sports Exerc.* 2018;50(1):116-123. doi:10.1249/MSS.0000000000001419.

- [29] Scrivin R, Slater G, Mika A, Rauch C, Young P, Martinez I, Costa RJS. The impact of 48 h high carbohydrate diets with high and low FODMAP content on gastrointestinal status and symptoms in response to endurance exercise, and subsequent endurance performance. *Appl Physiol Nutr Metab*. 2024;49(6):773-791. doi:10.1139/apnm-2023-0508.
- [30] Montero-Carrasco K, Arias-Tellez MJ, Soto-Sánchez J. Use of carbohydrate (CHO), gluten-free, and FODMAP-free diets to prevent gastrointestinal symptoms in endurance athletes: A systematic review. *Nutrients*. 2024;16(22):3852. doi:10.3390/nu16223852.
- [31] James LJ, Stevenson EJ, Rumbold PLS, Hulston CJ. Cow's milk as a post-exercise recovery drink: implications for performance and health. *Eur J Sport Sci*. 2019;19(1):40-48. doi:10.1080/17461391.2018.1534989.
- [32] Costa RJS, Camões-Costa V, Snipe RMJ, Dixon D, Russo I, Huschtscha Z. The impact of a dairy milk recovery beverage on bacterially stimulated neutrophil function and gastrointestinal tolerance in response to hypohydration inducing exercise stress. *Int J Sport Nutr Exerc Metab*. 2020;30(4):237-248. doi:10.1123/ijsnem.2019-0349.
- [33] Russo I, Della Gatta PA, Garnham A, Porter J, Burke LM, Costa RJS. Does the nutritional composition of dairy milk based recovery beverages influence post-exercise gastrointestinal and immune status, and subsequent markers of recovery optimisation in response to high intensity interval exercise? *Front Nutr*. 2021;7:622270. doi:10.3389/fnut.2020.622270.
- [34] Matsuda T, Ishikawa A, Kanno M, et al. The effect of co-ingestion of carbohydrate with milk after exercise in healthy women: study considering the menstrual cycle. *J Sports Sci Med*. 2022;21(2):191-199. doi:10.52082/jssm.2022.191.
- [35] Amiri M, Ghiasvand R, Kaviani M, Forbes SC, Salehi-Abargouei A. Chocolate milk for recovery from exercise: a systematic review and meta-analysis of controlled clinical trials. *Eur J Clin Nutr*. 2019;73(6):835-849. doi:10.1038/s41430-018-0187-x.
- [36] Jäger R, Kerksick CM, Campbell BI, et al. International Society of Sports Nutrition position stand: protein and exercise. *J Int Soc Sports Nutr*. 2017;14:20. doi:10.1186/s12970-017-0177-8.
- [37] Sale C, Elliott-Sale KJ. Nutrition and athlete bone health. *Sports Med*. 2019;49(Suppl 2):139-151. doi:10.1007/s40279-019-01161-2.
- [38] Mountjoy M, Ackerman KE, Bailey DM, et al. 2023 International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs). *Br J Sports Med*. 2023;57(17):1073-1097. doi:10.1136/bjsports-2023-106994.

- [39] Ramsing R, Santo R, Kim BF, Altema-Johnson D, Wooden A, Chang KB, Semba RD, Love DC. Dairy and plant-based milks: implications for nutrition and planetary health. *Curr Environ Health Rep.* 2023;10(3):291-302. doi:10.1007/s40572-023-00400-z.
- [40] Walther B, Guggisberg D, Badertscher R, et al. Comparison of nutritional composition between plant-based drinks and cow's milk. *Front Nutr.* 2022;9:988707. doi:10.3389/fnut.2022.988707.