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Quality in Sport. eISSN 2450-3118.

Journal Home Page

<https://apcz.umk.pl/QS/index>

PURPURA, Aleksandra, ROLSKI, Wiktor, PRZYBYLSKA, Zuzanna, MICHALSKA, Paulina, PRZYSTAŚ, Bartłomiej, GRZECHOWIAK, Magdalena, PODESZWA, Sebastian, HOBOT, Mikołaj and DOBOSZ, Gabriela. Exercise-induced gastrointestinal injury in endurance athletes: mechanisms, risk factors and clinical implications – a review. Quality in Sport. 2026;54:70038. eISSN 2450-3118. <https://doi.org/10.12775/QS.2026.54.70038>

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique 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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The authors declare that there is no conflict of interest regarding the publication of this paper.

Received: 20.03.2026. Revised: 30.03.2026. Accepted: 30.03.2026. Published: 02.04.2026.

Exercise-induced gastrointestinal injury in endurance athletes: mechanisms, risk factors and clinical implications – a review

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Abstract

Background.

Gastrointestinal (GI) disturbances are commonly reported among endurance athletes and significantly affect performance and health. Prolonged, high-intensity exercise leads to physiological stress responses impairing GI function. Mechanisms such as splanchnic

hypoperfusion, increased intestinal permeability, heat stress, and dehydration contribute to exercise-induced gastrointestinal syndrome.

Aim.

This review summarizes knowledge on exercise-induced GI injury in endurance athletes, focusing on epidemiology, pathophysiological mechanisms, risk factors, clinical manifestations, and management strategies.

Material and methods.

A literature search was conducted in PubMed, Scopus, Web of Science, and Google Scholar for studies up to 2025. Keywords related to GI symptoms, endurance exercise, intestinal permeability, and splanchnic hypoperfusion were used. Original research articles, systematic reviews, and meta-analyses were included.

Results.

GI symptoms like nausea, diarrhea, and bloating affect 30% to 90% of athletes depending on conditions. Mechanisms involve reduced splanchnic blood flow, epithelial injury, increased permeability, endotoxin translocation, systemic inflammation, and microbiota alterations. Risk factors include exercise duration, heat stress, dehydration, nutrition, and NSAID use. Severe complications like GI bleeding or ischemic colitis occur in rare cases.

Conclusions.

Exercise-induced GI injury is a multifactorial condition resulting from physiological, environmental, and nutritional stressors. Understanding these mechanisms and risk factors is essential for effective prevention and management strategies to protect GI health and optimize performance.

Key words: endurance exercise; gastrointestinal symptoms; intestinal permeability; splanchnic hypoperfusion; exercise-induced gastrointestinal syndrome.

1. Introduction

Regular physical activity is widely recognized as a key determinant of overall health and plays an important role in the prevention of many chronic diseases. In addition to its well-established benefits for the cardiovascular and musculoskeletal systems, physical activity also influences the functioning of the gastrointestinal (GI) tract. Moderate levels of exercise may positively affect gastrointestinal motility, metabolic regulation, and gut microbiota composition,

potentially reducing the risk of several gastrointestinal disorders such as colorectal cancer, diverticular disease, and constipation [1].

Despite these beneficial effects, strenuous and prolonged physical activity may also provoke gastrointestinal disturbances. Gastrointestinal symptoms are particularly common in endurance sports, including marathon running, triathlon, and ultra-endurance events. Athletes frequently report symptoms such as nausea, abdominal pain, bloating, diarrhea, and gastrointestinal bleeding during or after prolonged exercise. The prevalence of exercise-related gastrointestinal complaints varies widely depending on the type, intensity, and duration of exercise, but studies suggest that between 30% and 90% of endurance athletes may experience some form of gastrointestinal discomfort [2].

In recent years, increasing attention has been given to the concept of exercise-induced gastrointestinal syndrome, which describes a range of physiological disturbances affecting gastrointestinal integrity and function during strenuous exercise [3]. These disturbances are primarily associated with the redistribution of blood flow from the gastrointestinal tract to working muscles and the skin, resulting in reduced splanchnic perfusion and intestinal ischemia. Additionally, neuroendocrine responses triggered by exercise stress may impair gastrointestinal motility, absorption, and barrier function. As a consequence, intestinal epithelial damage, increased permeability, endotoxemia, and inflammatory responses may occur [3,4].

The pathophysiology of gastrointestinal disturbances during endurance exercise is complex and multifactorial. Factors such as exercise intensity and duration, dehydration, environmental heat stress, dietary practices, and individual susceptibility may all influence the occurrence and severity of gastrointestinal symptoms. These disturbances may not only affect athletic performance but may also have clinical implications for gastrointestinal health [4,5].

The aim of this review is to summarize current knowledge on exercise-induced gastrointestinal injury in endurance athletes, focusing on its epidemiology, underlying mechanisms, and clinical implications.

2. Research materials and methods

2.1. Search strategy

This review was conducted to summarize current evidence regarding exercise-induced gastrointestinal disturbances in endurance athletes. The literature search was performed in major scientific databases including PubMed, Scopus, Web of Science, and Google Scholar.

The search included studies published up to 2025. The following keywords and their combinations were used in the search strategy:

“exercise AND gastrointestinal symptoms”

“exercise-induced gastrointestinal syndrome”

“endurance exercise AND gastrointestinal disorders”

“gastrointestinal injury AND endurance athletes”

“exercise AND intestinal permeability”

“splanchnic hypoperfusion AND exercise”

Boolean operators (“AND”, “OR”) were applied to refine the search results. In addition, the reference lists of selected articles were manually screened to identify additional relevant studies that were not captured during the database search.

2.2. Eligibility criteria

Studies were included in the review if they met the following criteria:

original research articles, systematic reviews, or meta-analyses;

studies investigating gastrointestinal symptoms or gastrointestinal injury related to physical activity or exercise;

studies involving endurance or ultra-endurance athletes, including runners, cyclists, triathletes, or similar populations;

articles published in English;

studies providing information on the prevalence, mechanisms, or risk factors associated with exercise-induced gastrointestinal disturbances.

The following exclusion criteria were applied:

studies conducted exclusively on animals;

articles unrelated to physical activity or exercise;

conference abstracts, editorials, or opinion papers without original data;

studies focusing solely on gastrointestinal diseases not associated with exercise.

2.3. Data collection and analysis

2.3.1. Study selection process

The study selection process followed the general recommendations of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Initially, all records identified through database searching were screened based on their titles and abstracts. Articles considered potentially relevant were subsequently evaluated in full-text form. Duplicates were removed prior to screening. Studies that did not meet the predefined eligibility criteria were excluded during the title/abstract screening or full-text assessment stages.

The overall study selection process included four main stages:

Identification of studies through database searching,

Removal of duplicates,

Screening of titles and abstracts,

Eligibility assessment of full-text articles and final inclusion in the review.

2.3.2. AI

AI was utilized as an assistive instrument in the preparation of this research manuscript. Its application was focused on two specific areas:

Linguistic Refinement: Assistance in refining the academic English language, ensuring clarity, consistency, and adherence to scientific writing standards.

Structural Organization: Assistance in organizing the narrative structure to improve the coherence and flow of the literature review. It is important to emphasize that all AI tools were used strictly as assistive instruments under human supervision. The final interpretation of the literature, synthesis of evidence, and formulation of conclusions were determined solely by the authors. The AI tools served primarily to enhance efficiency in linguistic processing rather than replacing human judgment in the analytical process.

3. Epidemiology of gastrointestinal symptoms in endurance athletes

Gastrointestinal (GI) symptoms are frequently reported among athletes participating in endurance sports such as marathon running, triathlon, and ultramarathon events. Early studies investigating gastrointestinal function during prolonged exercise demonstrated that endurance athletes often experience abdominal complaints during long-lasting physical activity. These symptoms include nausea, abdominal pain, diarrhea, intestinal cramps, and other forms of gastrointestinal discomfort. Observational studies conducted among long-distance runners reported that gastrointestinal complaints may occur in a substantial proportion of participants, with some reports indicating that approximately 30–50% of endurance athletes experience GI disturbances during prolonged exercise [6].

Field studies conducted among runners participating in endurance competitions further confirm the high prevalence of gastrointestinal symptoms during long-distance running events. In a study examining runners competing in a 25-km race and a marathon, gastrointestinal complaints were reported by approximately one-quarter of runners in the 25-km race and by more than half of runners during the marathon. The most frequently reported symptoms included nausea, stomach pain, and side ache, while intestinal cramps and diarrhea were observed more often during the longer race distance. These findings suggest that the prevalence of gastrointestinal symptoms increases with longer race duration and greater physiological strain associated with marathon running [7].

Experimental laboratory studies also support the relationship between exercise duration and gastrointestinal disturbances. Research investigating endurance running performed for 1, 2, and 3 hours at moderate intensity demonstrated that gastrointestinal discomfort and the overall incidence of symptoms increased as exercise duration became longer [2]. Both upper and lower gastrointestinal symptoms were more frequently reported during the longer exercise trials, suggesting that prolonged exertion may disrupt gastrointestinal motility and gastric function, thereby contributing to the development of exercise-associated gastrointestinal symptoms [8].

The prevalence of gastrointestinal symptoms appears to be even higher during extreme endurance events such as ultramarathons. Studies conducted among ultramarathon runners have shown that gastrointestinal symptoms are extremely common during these events. For example, research examining runners participating in multi-stage and 24-hour ultramarathon

competitions reported that approximately 85% of athletes experienced at least one gastrointestinal symptom during the multi-stage event, while 73% reported symptoms during the continuous 24-hour race [4]. Moreover, the presence of gastrointestinal symptoms was associated with reduced energy intake and nutritional disturbances during competition, highlighting their potential impact on both performance and recovery [9].

Recent epidemiological studies continue to confirm the widespread occurrence of gastrointestinal symptoms among endurance athletes. A large survey involving 805 recreational long-distance runners reported that 26.1% of participants experienced gastrointestinal symptoms during races [6]. The most frequently reported symptoms included bloating, urge to defecate, and stomach pain. Additionally, the occurrence of gastrointestinal symptoms was influenced by several factors, including pre-race dietary habits, meal timing, training volume, and previous gastrointestinal history [10].

Overall, the available evidence indicates that gastrointestinal symptoms are a common feature of endurance sports, with prevalence increasing as exercise duration and physiological stress rise. Marathon and ultramarathon events appear to pose a particularly high risk for gastrointestinal disturbances, emphasizing the importance of understanding the epidemiology and contributing factors associated with exercise-induced gastrointestinal injury in endurance athletes.

4. Pathophysiological mechanisms of exercise-induced gastrointestinal injury

Exercise-induced gastrointestinal injury is a complex and multifactorial process that results from several interacting physiological mechanisms. These mechanisms primarily involve circulatory redistribution, epithelial injury, thermoregulatory stress, systemic inflammatory responses, and alterations in gut microbiota composition. Together, these factors contribute to impaired intestinal barrier integrity and the development of gastrointestinal symptoms frequently observed in endurance athletes.

4.1 Splanchnic hypoperfusion

One of the primary mechanisms responsible for gastrointestinal disturbances during endurance exercise is splanchnic hypoperfusion, which results from the redistribution of blood flow during physical activity. During exercise, a substantial proportion of cardiac output is redirected from the gastrointestinal tract to the working skeletal muscles and the skin in order to support metabolic demands and thermoregulation. As a result, blood flow to the splanchnic organs may decrease by up to 80% during intense exercise [11,12].

This reduction in intestinal blood flow can lead to intestinal ischemia, which compromises oxygen delivery to the intestinal mucosa and disrupts normal gastrointestinal function. Reduced perfusion of the intestinal wall may impair epithelial integrity and promote cellular injury. Experimental studies in healthy individuals have demonstrated that exercise-induced splanchnic hypoperfusion is associated with measurable intestinal injury, reflected by increases in circulating biomarkers of enterocyte damage, such as intestinal fatty acid-binding protein (I-FABP) [11]. Furthermore, the degree of hypoperfusion has been shown to correlate with the magnitude of intestinal injury and increased intestinal permeability.

Collectively, these findings suggest that the redistribution of blood flow away from the gastrointestinal tract during exercise represents a key initiating factor in the development of exercise-induced gastrointestinal injury.

4.2 Intestinal epithelial injury and permeability

Another important mechanism underlying exercise-induced gastrointestinal disturbances is damage to the intestinal epithelium and increased intestinal permeability. The intestinal epithelium forms a critical barrier that regulates the passage of nutrients, electrolytes, and microbial products between the intestinal lumen and the systemic circulation.

Several studies have demonstrated that prolonged endurance exercise can induce measurable injury to intestinal epithelial cells. Running-based studies have reported significant increases in circulating concentrations of intestinal fatty acid-binding protein (I-FABP) following prolonged exercise, indicating enterocyte damage and disruption of the intestinal barrier [13]. In addition, exercise has been shown to increase intestinal permeability, allowing the passage of larger molecules across the epithelial barrier.

The disruption of epithelial integrity is closely related to alterations in tight junction proteins, which regulate paracellular permeability between intestinal epithelial cells [13]. When tight junction integrity is compromised, the intestinal barrier becomes more permeable, a condition often referred to as “leaky gut.” Increased permeability may facilitate the translocation of bacterial components, such as lipopolysaccharides, from the intestinal lumen into the bloodstream.

Evidence from meta-analytic studies further supports the relationship between exercise and intestinal damage. A systematic review and meta-analysis demonstrated that a single bout of exercise significantly increases both markers of intestinal injury (such as I-FABP) and markers of intestinal permeability across multiple experimental protocols [14].

Several studies have also investigated nutritional strategies aimed at mitigating exercise-induced intestinal damage. For example, glutamine supplementation has been shown to reduce markers of intestinal permeability during running in hot conditions, suggesting a potential protective role for this amino acid in maintaining gut barrier integrity [15]. In contrast, supplementation with bovine colostrum has not consistently demonstrated protective effects against exercise-induced intestinal epithelial injury in hot environments [16]. Overall, systematic reviews indicate that certain nutritional strategies, including glutamine and carbohydrate intake, may partially attenuate exercise-associated gastrointestinal epithelial damage and permeability disturbances [17].

4.3 Heat stress and dehydration

Environmental stressors, particularly heat stress and dehydration, represent additional factors that exacerbate exercise-induced gastrointestinal injury. During prolonged exercise in hot conditions, increased thermoregulatory strain leads to elevated core body temperature and further redistribution of blood flow away from the gastrointestinal tract.

Experimental studies have shown that exertional heat stress significantly increases markers of intestinal epithelial injury and systemic inflammatory responses compared with exercise performed in temperate conditions [18,19]. Elevated core body temperature has been associated with increased levels of I-FABP, endotoxin concentrations, and inflammatory cytokines, indicating both intestinal damage and systemic immune activation [18].

Hydration status also plays an important role in modulating gastrointestinal integrity during exercise. Exercise-induced hypohydration may further impair gastrointestinal perfusion and

exacerbate gastrointestinal disturbances. Studies examining endurance running under hypohydrated conditions have reported increased markers of intestinal injury and higher incidence of gastrointestinal symptoms compared with euhydrated conditions [20].

In addition, thermoregulatory strain appears to be a key predictor of exercise-induced gastrointestinal injury. Research has demonstrated that increases in core body temperature during exercise are positively associated with markers of gastrointestinal epithelial damage and inflammatory responses [21]. Consequently, heat exposure and dehydration together represent important risk factors contributing to the development of exercise-induced gastrointestinal syndrome.

Preventive strategies aimed at reducing thermoregulatory strain, maintaining hydration, and optimizing nutritional intake may therefore help mitigate gastrointestinal disturbances during endurance exercise [22].

4.4 Endotoxemia and systemic inflammation

Damage to the intestinal epithelial barrier may allow bacterial components, particularly lipopolysaccharides (endotoxins) derived from Gram-negative bacteria, to translocate from the intestinal lumen into the systemic circulation. This process, known as exercise-induced endotoxemia, can trigger systemic inflammatory responses.

Clinical observations among endurance athletes have shown that elevated plasma endotoxin concentrations may occur following prolonged endurance events. For instance, studies conducted among exhausted runners after long-distance races reported that a large proportion of athletes exhibited increased circulating endotoxin levels, with many also reporting gastrointestinal symptoms such as nausea, vomiting, and diarrhea [23].

Endotoxin translocation can activate immune cells and stimulate the production of pro-inflammatory cytokines, contributing to systemic inflammation and exacerbation of gastrointestinal symptoms. This inflammatory response may also impair thermoregulation and contribute to fatigue and reduced athletic performance.

4.5 Gut microbiota

Recent research has highlighted the potential role of the gut microbiota in modulating gastrointestinal responses to exercise. The intestinal microbiota consists of a diverse

community of microorganisms that play important roles in metabolism, immune function, and maintenance of intestinal barrier integrity.

Endurance exercise has been shown to influence the composition and metabolic activity of the gut microbiota. While moderate exercise may promote beneficial microbial adaptations, prolonged or intense endurance exercise may disrupt microbial balance and contribute to gastrointestinal disturbances [24].

Emerging evidence suggests that the composition of the gut microbiota may influence the susceptibility to exercise-induced gastrointestinal injury. Studies investigating endurance athletes have demonstrated associations between specific bacterial taxa and markers of intestinal epithelial damage, systemic inflammation, and gastrointestinal symptoms following exertional heat stress [25,26].

Additionally, alterations in microbiota composition may interact with intestinal permeability and immune responses, potentially influencing the development and severity of exercise-induced gastrointestinal syndrome. Therefore, the gut microbiota is increasingly recognized as an important factor in the complex pathophysiology of gastrointestinal disturbances in endurance athletes [25].

5. Risk factors for gastrointestinal injury

Exercise-induced gastrointestinal injury is influenced by several intrinsic and extrinsic factors that may increase susceptibility to gastrointestinal disturbances during endurance exercise. Among the most important risk factors are exercise intensity and duration, environmental conditions such as heat stress and dehydration, nutritional practices and supplementation, and the use of medications such as non-steroidal anti-inflammatory drugs (NSAIDs).

5.1 Exercise intensity and duration

Exercise duration and intensity represent key determinants of gastrointestinal disturbances during endurance activity. Prolonged exercise increases physiological strain and contributes to disturbances in gastrointestinal motility, epithelial integrity, and nutrient absorption. Experimental studies investigating endurance running protocols of varying duration have shown that gastrointestinal symptoms increase with longer exercise bouts. For example, gastrointestinal symptom incidence and severity were significantly greater during two- and

three-hour running sessions compared with shorter one-hour exercise protocols, suggesting that prolonged exertion increases the likelihood of gastrointestinal discomfort and functional disturbances [8].

Ultra-endurance events represent an extreme example of the relationship between exercise duration and gastrointestinal disturbances. Studies examining ultramarathon competitions have reported a very high prevalence of gastrointestinal symptoms among participants. In multi-stage and continuous ultramarathon events, gastrointestinal symptoms have been reported by approximately 73–85% of athletes, with symptoms including nausea, vomiting, abdominal discomfort, and diarrhea [9]. Moreover, the severity of gastrointestinal symptoms during such events may negatively influence nutritional intake and hydration status, which may further compromise athletic performance and recovery.

These findings indicate that prolonged exercise duration, particularly in endurance and ultra-endurance events, represents a major risk factor for the development of exercise-associated gastrointestinal symptoms.

5.2 Heat and dehydration

Environmental stressors, particularly heat stress and dehydration, are well-recognized risk factors for gastrointestinal injury during endurance exercise. Exercise performed in hot environments increases thermoregulatory strain and promotes further redistribution of blood flow away from the gastrointestinal tract toward working muscles and the skin. This process exacerbates splanchnic hypoperfusion and may contribute to intestinal ischemia and epithelial injury.

Experimental studies have demonstrated that endurance exercise performed under hot environmental conditions results in greater intestinal epithelial damage compared with exercise performed in temperate environments. Elevated core body temperature during exertional heat stress has been associated with increased concentrations of biomarkers of intestinal injury, including intestinal fatty acid-binding protein (I-FABP), as well as increased gastrointestinal symptom severity and systemic inflammatory responses [18].

Hydration status may also influence gastrointestinal integrity during exercise. Exercise-induced hypohydration can increase cardiovascular and thermoregulatory strain and may exacerbate gastrointestinal disturbances. Research examining endurance running with restricted fluid intake has reported modest increases in markers of intestinal injury and gastrointestinal

symptoms under hypohydrated conditions compared with euhydrated conditions [20]. Additionally, increases in core body temperature during exercise have been shown to predict the magnitude of gastrointestinal injury and systemic inflammatory responses associated with exercise-induced gastrointestinal syndrome [21].

Together, these findings suggest that environmental heat stress and inadequate hydration significantly increase the risk of gastrointestinal disturbances during endurance exercise.

5.3 Nutrition and supplementation

Nutritional practices and dietary supplementation may also influence the occurrence and severity of gastrointestinal disturbances during exercise. Several nutritional strategies have been investigated as potential methods to reduce intestinal epithelial damage and improve gastrointestinal barrier integrity.

A systematic review examining dietary supplements for exercise-associated gastrointestinal injury indicated that several nutritional interventions, including glutamine, bovine colostrum, probiotics, carbohydrate intake, and adequate hydration strategies, may reduce markers of intestinal epithelial damage and permeability in response to endurance exercise [17]. Among these interventions, glutamine supplementation has demonstrated promising results in reducing markers of intestinal permeability during endurance running performed in hot environments [15].

In contrast, supplementation with bovine colostrum has not consistently demonstrated protective effects against exercise-induced intestinal epithelial injury. Studies investigating endurance exercise in hot and humid conditions reported increases in I-FABP concentrations following exercise regardless of bovine colostrum supplementation, suggesting limited effectiveness of this strategy in preventing enterocyte damage under thermal stress conditions [16].

Probiotic supplementation has also been explored as a potential strategy for mitigating gastrointestinal disturbances in athletes. Systematic reviews indicate that probiotics may contribute to reductions in gastrointestinal symptoms and inflammatory responses in some athletes, although findings remain inconsistent due to variability in probiotic strains, dosage, and supplementation duration [27].

Overall, while certain nutritional strategies may help attenuate gastrointestinal injury during endurance exercise, further research is needed to establish consistent and evidence-based recommendations.

5.4 NSAID use

The use of non-steroidal anti-inflammatory drugs (NSAIDs) represents an additional risk factor for gastrointestinal injury in athletes. NSAIDs are commonly used in sport to manage pain or inflammation; however, these medications are known to negatively affect gastrointestinal mucosal integrity.

Experimental studies examining ibuprofen use prior to exercise have shown that NSAID consumption can significantly increase markers of small intestinal injury and intestinal permeability during physical exertion. Athletes who consumed ibuprofen before exercise exhibited higher plasma concentrations of intestinal fatty acid-binding protein (I-FABP) compared with exercise performed without NSAID intake, indicating increased enterocyte damage and compromised intestinal barrier integrity [28].

These findings suggest that NSAID use may exacerbate exercise-induced gastrointestinal injury and increase susceptibility to gastrointestinal disturbances during endurance exercise.

6. Clinical manifestations and complications

Exercise-induced gastrointestinal disturbances may present with a wide spectrum of clinical manifestations ranging from mild gastrointestinal discomfort to severe pathological conditions. While most symptoms experienced by endurance athletes are transient and self-limiting, in some cases gastrointestinal disturbances may progress to clinically significant complications, including gastrointestinal bleeding and ischemic colitis. The severity of symptoms depends on multiple factors, including exercise intensity, duration, hydration status, and individual susceptibility.

6.1 Gastrointestinal symptoms

Gastrointestinal symptoms are among the most frequently reported health complaints in endurance athletes. Previous studies indicate that approximately 30–50% of athletes participating in endurance events experience at least one gastrointestinal symptom during

exercise [2]. These symptoms are particularly common in sports involving prolonged running, such as marathons and ultramarathons.

The most commonly reported symptoms include nausea, diarrhea, abdominal pain, and bloating, which may occur during exercise or shortly after completion of endurance events. Gastrointestinal disturbances are often categorized as either upper gastrointestinal symptoms (such as nausea or vomiting) or lower gastrointestinal symptoms, including diarrhea, abdominal cramping, and urgency to defecate [2]. According to the review on gastrointestinal complaints during exercise, the prevalence and severity of symptoms vary depending on environmental conditions, exercise intensity, nutritional factors, and individual susceptibility among athletes [2].

Observational studies conducted among endurance runners have confirmed the high prevalence of gastrointestinal complaints during prolonged exercise. Early investigations examining long-lasting exercise demonstrated that approximately 30–50% of long-distance runners reported abdominal complaints, including stomach pain, intestinal cramps, and diarrhea during endurance activity [6]. These symptoms are thought to result from a combination of physiological factors such as reduced splanchnic blood flow, mechanical stress associated with running, and nutritional influences.

Field studies conducted during endurance races further support these findings. Research investigating runners participating in both a 25-km race and a marathon showed that gastrointestinal complaints were common during both events, with symptoms such as nausea, stomach ache, and side ache frequently reported by participants. Importantly, the prevalence of gastrointestinal complaints was substantially higher during the marathon compared with the shorter race distance, suggesting that symptom occurrence increases with longer exercise duration and greater physiological strain [7].

More recent epidemiological data confirm that gastrointestinal symptoms remain common among recreational endurance athletes. A large survey involving 805 recreational long-distance runners reported that approximately 26.1% of participants experienced gastrointestinal symptoms during races, with bloating, urge to defecate, and stomach pain being the most frequently reported complaints [10]. Nutritional strategies, meal timing before the race, and training volume were identified as important factors influencing symptom occurrence [10].

Taken together, these findings indicate that gastrointestinal symptoms such as nausea, diarrhea, abdominal pain, and bloating represent common manifestations of exercise-associated gastrointestinal syndrome in endurance athletes.

6.2 Gastrointestinal bleeding and ischemic colitis

Although most gastrointestinal symptoms associated with endurance exercise are mild, more severe gastrointestinal complications may occasionally occur. One of the most clinically significant manifestations is gastrointestinal bleeding, which has been reported in athletes participating in strenuous endurance events. Gastrointestinal bleeding in athletes may originate from either the upper or lower gastrointestinal tract and may be related to factors such as splanchnic hypoperfusion, mechanical trauma to the gastrointestinal wall, or the use of non-steroidal anti-inflammatory drugs (NSAIDs) [29].

Lower gastrointestinal bleeding in endurance athletes is often associated with **exercise-induced ischemic colitis**, a rare but potentially serious condition resulting from reduced blood flow to the colon during intense physical exertion. Case reports have described athletes presenting with symptoms such as severe abdominal pain, bloody diarrhea, and hematochezia following endurance events [30]. Typical clinical presentation includes cramp-like abdominal pain accompanied by multiple loose stools containing visible blood.

Several case reports and clinical observations have documented ischemic colitis in endurance runners. Reports involving marathon participants have described patients presenting with abdominal pain and bloody diarrhea shortly after completing a race, with diagnostic investigations confirming ischemic colitis [31]. In some cases, the condition may develop within hours following the race and may be associated with dehydration and reduced mesenteric blood flow.

Case-based reviews of marathon runners presenting to emergency departments emphasize that ischemic colitis should be considered in athletes who present with abdominal pain and rectal bleeding after endurance events [32]. Clinical manifestations may include abdominal cramping, diarrhea, and hematochezia, and in rare cases more severe complications requiring medical intervention may occur.

Additional case reports have described marathon-induced ischemic colitis resulting from a combination of splanchnic vasoconstriction, dehydration, and mechanical stress associated with prolonged running [33]. Although most cases resolve with supportive treatment and fluid therapy, severe cases requiring surgical intervention have also been reported.

Other documented cases of exercise-induced ischemic colitis describe runners presenting with acute abdominal pain and bloody diarrhea following endurance competitions, with diagnostic

imaging or colonoscopy revealing ischemic changes in the colon [34]. Exercise-induced colon ischemia remains a rare condition but should be recognized as a possible complication of prolonged endurance exercise.

Recent reports have also described novel therapeutic approaches in athletes experiencing recurrent exercise-induced colon ischemia, including pharmacological interventions aimed at improving intestinal perfusion and maintaining adequate blood pressure during exercise [35]. Despite the rarity of these severe complications, awareness of their clinical presentation is essential for early diagnosis and appropriate management.

7. Prevention and management strategies

Given the high prevalence of gastrointestinal disturbances among endurance athletes, the development of effective prevention and management strategies has become an important area of research. Current evidence suggests that strategies aimed at maintaining gastrointestinal integrity during exercise should focus on adequate hydration, appropriate nutritional practices, heat stress management, and targeted supplementation.

Hydration strategies

Maintaining adequate hydration during prolonged exercise is considered a fundamental strategy for minimizing gastrointestinal disturbances. Hypohydration and reduced plasma volume can exacerbate splanchnic hypoperfusion, thereby increasing the risk of intestinal epithelial injury and gastrointestinal symptoms during endurance activity.

Hydration strategies that include regular fluid intake before and during exercise may help attenuate thermoregulatory strain and support gastrointestinal function during endurance exercise. Studies examining fluid temperature during exertional heat stress have shown that ingestion of cold or cool water (approximately 0–7°C) during prolonged running can reduce the rise in core body temperature and attenuate thermoregulatory strain compared with water consumed at ambient temperature [19].

Although such strategies may not completely eliminate gastrointestinal symptoms, they may contribute to modest reductions in intestinal epithelial injury and improve thermal comfort during endurance exercise [19]. Although such strategies may not completely eliminate gastrointestinal symptoms, they may contribute to modest reductions in intestinal epithelial injury and improve thermal comfort during endurance exercise [19].

Heat management

Environmental heat exposure is a major factor contributing to exercise-induced gastrointestinal disturbances. Elevated ambient temperatures increase thermoregulatory strain and further reduce blood flow to the gastrointestinal tract, thereby exacerbating intestinal injury and systemic inflammatory responses.

Research investigating exercise in hot environments has demonstrated that prolonged running under heat stress conditions significantly increases markers of intestinal epithelial injury and gastrointestinal symptoms compared with exercise performed in temperate conditions. Preventive strategies aimed at reducing heat stress include optimizing hydration status, implementing cooling strategies, and adjusting exercise intensity during hot conditions.

Practical recommendations include the ingestion of cool fluids during exercise, maintaining adequate carbohydrate intake, and implementing cooling strategies before and during endurance activity to limit hyperthermia and maintain gastrointestinal integrity [22]. These strategies may help mitigate the physiological mechanisms responsible for exercise-induced gastrointestinal syndrome [22].

Nutritional strategies

Nutritional practices before and during exercise also play an important role in maintaining gastrointestinal function. Carbohydrate intake during prolonged endurance exercise may support intestinal integrity by improving energy availability and reducing the severity of splanchnic hypoperfusion.

A systematic review evaluating dietary supplementation strategies suggests that several nutritional interventions—including carbohydrate intake, maintenance of euhydration, and specific supplements—may reduce markers of intestinal epithelial damage and permeability associated with endurance exercise [17]. Although the effectiveness of individual strategies varies depending on exercise conditions and athlete characteristics, appropriate nutritional planning remains an essential component of gastrointestinal health in endurance sports [17].

Supplementation strategies

Various dietary supplements have been investigated for their potential protective effects against exercise-induced gastrointestinal injury. Among these, glutamine supplementation has received particular attention due to its role as an important metabolic substrate for intestinal epithelial cells. Experimental studies have demonstrated that acute glutamine supplementation prior to endurance exercise in hot conditions may attenuate increases in markers of intestinal permeability, suggesting a protective effect on intestinal barrier integrity [15].

Probiotics have also been investigated as a potential strategy to support gastrointestinal and immune function in athletes. Evidence from systematic reviews suggests that probiotic supplementation may contribute to improvements in gastrointestinal health, reductions in inflammatory markers, and potential reductions in exercise-related fatigue in some athletic populations [27]. However, the effectiveness of probiotic interventions appears to depend on the specific bacterial strains, dosage, and duration of supplementation.

Overall, the current body of evidence indicates that no single intervention completely prevents exercise-induced gastrointestinal disturbances. Instead, a multifactorial approach combining hydration strategies, heat management, appropriate nutrition, and targeted supplementation may represent the most effective strategy for reducing the risk of gastrointestinal injury in endurance athletes.

8. Clinical implications for athletes and clinicians

Exercise-induced gastrointestinal disturbances may have important clinical implications for both athletes and healthcare professionals involved in sports medicine and endurance training. Although many gastrointestinal symptoms experienced during endurance exercise are transient and self-limiting, their occurrence can negatively affect athletic performance, nutritional intake, and overall health status.

Monitoring athletes and recognizing symptoms

Effective monitoring of athletes during endurance training and competition is essential for early recognition of gastrointestinal disturbances. Studies conducted among ultramarathon runners demonstrate that gastrointestinal symptoms frequently occur during prolonged endurance events and may significantly affect nutritional intake and hydration status. In one study involving ultramarathon competitions, gastrointestinal symptoms were reported by 85% of runners in a multi-stage ultramarathon and 73% in a 24-hour race, and the presence of these symptoms was associated with reduced energy and macronutrient intake during the event [9].

As shown in the analysis of ultramarathon participants (page 1–2 of the article), gastrointestinal symptoms such as nausea, vomiting, diarrhea, and abdominal pain were common during competition and were associated with disturbances in energy balance and nutrient intake [9]. These findings highlight the importance of systematic monitoring of symptoms during endurance events in order to prevent deterioration of nutritional status and performance.

For clinicians and sports medicine practitioners, recognizing early gastrointestinal symptoms is particularly important because these symptoms may precede more severe gastrointestinal complications. Symptoms such as persistent abdominal pain, diarrhea, nausea, or hematochezia should prompt further medical evaluation to exclude underlying gastrointestinal injury.

Gastrointestinal bleeding and severe complications

Although most gastrointestinal complaints experienced by athletes are mild, more severe complications may occur in rare cases. Gastrointestinal bleeding has been reported among endurance athletes and may occur in both the upper and lower gastrointestinal tract. It is often associated with factors such as splanchnic hypoperfusion, mechanical trauma of the intestinal wall during running, and the use of nonsteroidal anti-inflammatory drugs [29].

Evidence suggests that gastrointestinal bleeding in athletes may sometimes remain occult and self-limited, which may lead to underdiagnosis. However, in certain cases it may contribute to anemia, impaired performance, and more serious gastrointestinal pathology requiring clinical investigation and management. Therefore, clinicians should consider gastrointestinal bleeding in athletes presenting with symptoms such as abdominal pain, fatigue, or bloody stools.

Exercise-induced ischemic colitis

Another clinically relevant complication observed in endurance athletes is exercise-induced ischemic colitis, which is believed to result from transient reduction of mesenteric blood flow during intense physical exertion. Case reports have described endurance athletes presenting with abdominal pain and hematochezia following long-distance running. These symptoms are thought to arise from temporary mesenteric vasoconstriction and reduced intestinal perfusion during exercise [35].

Clinical evaluation of suspected exercise-induced ischemic colitis typically involves imaging and endoscopic investigations in order to exclude other gastrointestinal disorders. Management strategies generally include temporary reduction of exercise intensity, optimization of hydration status, and medical monitoring. In rare cases of recurrent symptoms, pharmacological interventions aimed at improving mesenteric blood flow may be considered [35].

Practical implications for prevention

From a practical perspective, prevention of gastrointestinal complications in endurance athletes should focus on early symptom recognition, adequate hydration and nutritional strategies, and individualized training approaches. Athletes and coaches should be educated to recognize early gastrointestinal warning signs and to modify training intensity or environmental exposure when symptoms occur.

Healthcare professionals working with endurance athletes should implement regular monitoring strategies and provide guidance on nutrition, hydration, and medication use during training and competition. Early recognition and appropriate management of gastrointestinal disturbances may help reduce the risk of more severe complications and support both athletic performance and long-term gastrointestinal health.

9. Future research directions

Despite the growing body of literature on exercise-induced gastrointestinal disturbances, several important areas require further investigation. Current knowledge regarding the mechanisms, biomarkers, and long-term consequences of gastrointestinal injury during endurance exercise remains incomplete, highlighting the need for future interdisciplinary research integrating physiology, nutrition, and microbiome science.

Biomarkers of gastrointestinal injury

Future studies should focus on improving the identification and interpretation of biomarkers that reflect gastrointestinal damage and intestinal permeability during exercise. Indirect markers such as intestinal fatty acid-binding protein (I-FABP) are widely used to estimate enterocyte injury; however, their diagnostic sensitivity and specificity in athletic populations remain an area of ongoing investigation.

A systematic review and meta-analysis demonstrated that a single bout of exercise significantly increases markers of gastrointestinal epithelial damage and intestinal permeability, particularly in endurance exercise protocols and in hot environmental conditions [14]. These findings highlight the need for further research aimed at identifying reliable biomarkers that can be used for early detection of gastrointestinal injury in athletes and for monitoring the effectiveness of preventive interventions. Future research should also explore the interaction between physiological stressors, environmental conditions, and individual susceptibility to gastrointestinal damage.

Role of gut microbiota in exercise-induced gastrointestinal syndrome

The role of the gut microbiota in modulating gastrointestinal responses to endurance exercise has recently gained increasing attention. The intestinal microbiota is a complex ecosystem consisting of hundreds of bacterial species that influence metabolic processes, immune responses, and intestinal barrier integrity. Emerging evidence suggests that alterations in

microbiota composition may influence gastrointestinal function, inflammation, and exercise performance.

Recent reviews emphasize that endurance exercise may influence both gastrointestinal function and microbial composition, while the gut microbiota may in turn affect nutrient absorption, recovery processes, and susceptibility to gastrointestinal symptoms in athletes [25]. However, current findings remain inconsistent, partly due to methodological differences across studies, including variations in dietary control, training status, and microbiome analysis techniques. Therefore, well-controlled longitudinal studies are needed to better understand the relationship between exercise training and microbiota adaptations.

Experimental studies have also investigated the association between gut microbiota composition and physiological responses to exercise-induced stress. For example, research examining endurance athletes exposed to exertional heat stress demonstrated that the relative abundance of specific bacterial taxa may be associated with the magnitude of intestinal epithelial injury, systemic inflammatory responses, and gastrointestinal symptoms during exercise [26]. These findings suggest that microbiota composition may influence an individual's susceptibility to exercise-induced gastrointestinal syndrome.

Future perspectives

Future research should aim to integrate microbiome science, exercise physiology, and nutritional strategies in order to better understand the mechanisms underlying gastrointestinal disturbances during endurance exercise. Particular attention should be given to longitudinal studies investigating microbiota adaptations in athletes, the development of personalized nutritional interventions, and the identification of novel biomarkers capable of detecting early gastrointestinal injury.

A deeper understanding of these mechanisms may contribute to the development of targeted prevention strategies that improve gastrointestinal health, athletic performance, and recovery in endurance athletes.

10. Conclusion

Exercise-induced gastrointestinal disturbances represent a common and multifactorial problem among endurance athletes. Prolonged and high-intensity exercise leads to significant physiological stress, including redistribution of blood flow away from the gastrointestinal tract, increased core body temperature, and dehydration. These factors contribute to splanchnic hypoperfusion, which may result in intestinal ischemia and epithelial injury.

Damage to the intestinal barrier increases gastrointestinal permeability and may facilitate the translocation of endotoxins and other bacterial components into the systemic circulation. This cascade of physiological events may trigger inflammatory responses and contribute to the development of gastrointestinal symptoms commonly reported by endurance athletes, including nausea, abdominal pain, diarrhea, and bloating. In more severe cases, gastrointestinal bleeding or ischemic colitis may occur.

Understanding the complex interaction between exercise intensity, environmental stressors, nutritional factors, and individual susceptibility is essential for the effective prevention and management of exercise-induced gastrointestinal syndrome. Future research should focus on identifying reliable biomarkers, optimizing nutritional strategies, and exploring the role of gut microbiota in order to develop targeted interventions that support gastrointestinal health and athletic performance in endurance athletes.

Disclosure

Supplementary Materials: None

Author Contributions: Conceptualization, A.P. and W.R.; Methodology, Z.P.; Software, P.M.; Check, A.P., B.P. and M.G.; Formal Analysis, S.P.; Investigation, M.H.; Resources, G.D.; Data Curation, A.P.; Writing – rough preparation, W.R.; Writing – review and editing, P.M.; Visualization, Z.P.; Supervision, A.P.; Project Administration, A.P.

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

Funding: This research was conducted without any specific funding from public, commercial, or nonprofit organizations.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data analyzed during this study are included in this published article and are available from the cited literature.

Conflict of interest: The authors declare there are no conflicts of interest.

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

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

In preparing this work, the authors used ChatGPT (OpenAI) for the purpose of improving language and readability as well as translating specific terms. After using this tool, the authors

have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

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