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## Exercise-Induced Bronchoconstriction in Athletes: Pathophysiology, Diagnosis and Management - a literature review

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## **ABSTRACT**

### **Introduction**

Exercise-induced bronchoconstriction (EIB) is a transient lower airway narrowing occurring during or post-vigorous physical activity. Unlike exercise-induced asthma (EIA), characterized by chronic inflammation, EIB affects both asthmatic and non-asthmatic individuals. It is the primary chronic condition in elite athletes, with prevalence reaching 70% in endurance disciplines. Untreated EIB impairs respiratory health, mental well-being, and sports performance.

## **Materials and Methods**

A systematic literature search was conducted, based on the following databases: Embase, PubMed, Cochrane Library, and Google Scholar, in reference to PRISMA guidelines. The keyword choice was decided beforehand in relation to the subject of the review.

## **The Stage of Knowledge**

EIB pathophysiology centers on the hyperosmolar theory. Intense hyperventilation causes evaporative water loss and airway cooling. This osmotic shift and rapid rewarming trigger mast cell degranulation, releasing inflammatory mediators like cysteinyl leukotrienes (CysLTs) that cause smooth muscle contraction. Environmental factors heavily exacerbate this: cold air, low humidity, pollution, toxins, causing the disruption of epithelial barriers

## **Summary**

EIB is a major health burden for athletes. Accurate diagnosis is vital to differentiate isolated EIB from chronic asthma. Effective management uses pharmacological treatments, like CysLT receptor antagonists, alongside dietary interventions, including Vitamin C, Omega-3, and gut microbiota modulation. These interventions mitigate inflammation, prevent irreversible remodeling, and optimize athletic performance.

**Key words:** exercise-induced bronchoconstriction, airway hyperresponsiveness, athletes, respiratory health, physical activity

## **1. Introduction**

Exercise-induced bronchoconstriction (EIB) describes the transient narrowing of the lower airways that occurs during or after vigorous physical activity, regardless of the presence of underlying asthma (1, 2, 3). The obstruction is typically temporary, manifesting 5–15 minutes after exercise (4), and presents with symptoms such as coughing, dyspnea, wheezing, chest tightness, and increased fatigue (5). Importantly, EIB can occur in individuals both with and without a prior diagnosis of asthma (2, 4, 6).

### **2.1 Significance of the Problem in Athlete Populations**

EIB is considered the most common chronic disease among elite athletes and, when left untreated, can significantly impact both respiratory health and sports performance (7). Among

athletes competing at elite levels, the prevalence of respiratory conditions is notably elevated, ranging from 20% to 70% depending on the specific sport (8). Beyond physical performance, symptoms of EIB in athletes with asthma are associated with a significantly higher proportion reporting feelings of fearfulness, frustration, isolation, depression, and embarrassment compared with those without symptoms (6).

The consequences of inadequate management extend beyond performance impairment - untreated airway inflammation can result in epithelial damage, airway remodeling, and fibrosis (9), underscoring the critical importance of early and accurate diagnosis. In recent years, awareness and detection of EIB among elite athletes has increased considerably (7).

## **2.2 Difference Between EIB and Exercise-Induced Asthma**

The terms "exercise-induced asthma" (EIA) and "exercise-induced bronchoconstriction" (EIB) have historically been used interchangeably (10), yet they refer to two clinically distinct conditions (4). EIA is a true pathological entity, characterized by bronchial hyperreactivity and chronic airway inflammation, whereas EIB represents a transitory airway narrowing that may occur even in non-asthmatic individuals (4).

The term EIB is currently preferred in clinical and scientific practice, as exercise is not considered an independent risk factor for asthma, but rather a trigger of bronchoconstriction in susceptible individuals (3). Accordingly, EIB encompasses both patients with chronic asthma in whom exercise provokes bronchoconstriction, and patients who develop exercise-related airway narrowing in the absence of chronic asthma (3). When the distinction is necessary, EIA is used specifically when bronchoconstriction is associated with underlying asthma symptoms, while EIB refers more broadly to the bronchoconstrictive response itself (10).

Furthermore, research suggests that asthma in athletes may represent at least two distinct endotypes: classic early-onset, Type 2-mediated asthma, and a later-onset form triggered by years of intensive exercise training, which may be classified as non-Type 2 asthma (11).

## **2.3 Prevalence in Different Sports Disciplines**

The prevalence of EIB varies considerably depending on the sport, training environment, and individual genetic predisposition (8). Asthma is estimated to affect 15-30% of Olympic athletes overall, with particularly high rates among those competing in endurance

disciplines such as swimming, long-distance running, and cycling (8). EIB also affects more than 10% of otherwise healthy individuals, as demonstrated by epidemiological studies (10).

Athletes engaged in endurance sports, winter sports, and water sports consistently show the highest prevalence of EIB (7, 12). The role of the training environment is well illustrated by the observation that the prevalence of EIB is ninefold greater in swimmers compared with boxers (13). More broadly, athletes who train and compete in environments requiring sustained high ventilation rates appear to have heightened susceptibility to EIB (13). In some sports, lower airway dysfunction - encompassing asthma and EIB - affects more than half of all competing athletes (9).

## **2.4 Epidemiology of Exercise-Induced Bronchoconstriction in Athletes**

Public EIB prevalence is highly dependent on previous asthma diagnosis. While in the general population, EIB applies to 5-20%, for individuals with established asthma EIB occurs in approximately 90% (6). For athletes, susceptibility is significantly higher. Prevalence ranges around 7-70%, without significant differences across sex (14). The highest risk of developing EIB applies to endurance sports, like long-distance running, cycling and triathlons. Prevalence typically ranges 20-50%. The risk of EIB does not increase in asthmatic athletes when compared with nonatopic athletes (15).

Pathogenesis of EIB in athletes is heavily driven by multiple risk factors associated with endurance disciplines. Prolonged intense training requires a switch from nasal to mouth breathing, which bypasses warming and humidifying of inhaled air. Moreover, purification of air is impaired, which leads to a higher rate of pollutants and aeroallergens entering the airways (15,16). In winter sports increases risk of mucosal cooling and localized osmotic shock, hyperosmolar shifts and reactive hyperemia due to cold air (15,16). In water sports, athletes are exposed to inhalation of trichloramine and nitrogen trichloride gases that gather directly over the pool's surface. These chemical compounds act as epithelial toxins, disrupting tight junctions in the bronchial lining and damaging respiratory epithelium when combined with gasping (8,17). In combination with high-volume airflow evaporating the mucous layer, exacerbation of bronchial hyperresponsiveness is much more plausible (16).

## **2.5 The pathophysiology of exercise-induced bronchoconstriction and methods of prevention**

The pathophysiology of exercise-induced bronchoconstriction is complex, as there are many distinct causes (6, 18, 19). One of the most significant is the osmotic theory, which suggests that physical exertion leads to increased water loss from the surface of the airways (6). This is because, during normal breathing, the body humidifies and warms the air reaching the more distal airways (20). Hyperventilation, which occurs during intense exercise, leads to increased water loss through evaporation, drying out and cooling of the airways, which reduces the volume of interstitial fluid. This phenomenon induces mast cell degranulation, resulting in the release of inflammatory mediators and exacerbating asthma symptoms, as molecules such as prostaglandin D<sub>2</sub>, cysteinyl leukotrienes, histamine and tryptase mediate bronchial smooth muscle contraction, increase mucus production and enhance microvascular permeability (6, 12, 18, 19).

Physical exertion causes the airways to cool down initially, which affects the blood vessels. The subsequent rapid warming causes a sudden dilation of the blood vessels, resulting in swelling and congestion of the mucous membrane. These phenomena lead to obstruction, i.e. narrowing of the airways (21). It is worth noting that the nasal passages are more effective at filtering and trapping inhaled dust and other airborne pollutants, and during exercise the airway shifts from the nose to the mouth (19). Furthermore, dysfunction of the airway epithelium has been demonstrated in the pathogenesis of EIB in athletes (21). This may be caused by physical damage to cells, impaired barrier function, inhalation of large amounts of dry, cold air, or changes in the osmolarity of the fluid covering the epithelium (20, 22).

Many mediators are involved in the pathogenesis of EIB; however, some of them, such as prostaglandin E<sub>2</sub>, dilate the airways. It has been found that their expression is reduced during physical exertion, which exacerbates asthma attacks (12). From the perspective of EIB, an important inflammatory mediator is CysLT, produced as part of the arachidonic acid cascade, which is generated by, amongst others, mast cells, eosinophils and epithelial cells (12). For this reason, an effective method of preventing exercise-induced asthma is the use of drugs that block CysLT receptors (23). For this purpose, preparations that inhibit the action of the enzyme 5-lipoxygenase, which is important for arachidonic acid metabolism, and drugs that directly block the CysLT<sub>1</sub> receptor are used (24).

Another method for preventing exercise-induced asthma is dietary supplementation, which has been shown to significantly reduce asthma symptoms in the case of low-salt diets, vitamin C intake and omega-3 fatty acids (21). A number of studies have shown that acute vitamin C supplementation significantly reduced the post-exercise decline in FEV1 by 0.24% compared with placebo (25). It has also been demonstrated that omega-3 fatty acids reduce bronchial inflammation by lowering arachidonic acid levels in neutrophils and attenuating the late airway response to allergens (21).

It is worth noting that the gut microbiota plays a significant role in asthma symptoms in athletes, as it has been shown to have a significant immunomodulatory effect (26). By releasing relevant factors systemically, it can directly modify the immune responses of the respiratory system (11). For this reason, the gut-lung axis represents a promising therapeutic target (11, 26) through dietary supplementation with live microorganisms that confer health benefits to the host (27).

## **2.6 The Prevalence and Environmental Triggers of Exercise-Induced Bronchoconstriction in Athletes**

Exercise-induced bronchoconstriction (EIB), previously referred to as exercise induced bronchospasm, is a highly prevalent respiratory condition affecting a significant portion of the active population. Current epidemiological data indicates that up to 26% of athletes may suffer from this condition (28), a figure that is starkly higher than the prevalence found in the general population.

The fundamental clinical distinction in diagnosing and treating this condition lies in whether the EIB occurs in a patient with a pre-existing diagnosis of chronic asthma (often termed EIBa) or in individuals without clinical asthma. For asthmatic patients, intense exertion acts as a potent trigger, exacerbating baseline airway hyperresponsiveness. This underlying diagnosis of asthma can fully explain the acute symptoms they experience post-exercise, such as wheezing, excessive coughing, shortness of breath (dyspnea), and a severe sensation of chest tightness (29).

The global burden of respiratory diseases is substantial. It is currently estimated that approximately 8.8% to 11.3% of the global population is asthmatic (30), with rates steadily climbing in highly urbanized and industrialized nations. Even more concerning is the clear upward trajectory of these respiratory diseases among younger demographics. Recent

systematic reviews indicate that up to 15% to 20% of athletic children and adolescents are now diagnosed with asthma, a very concerning trend for public health officials and sports medicine professionals (17).

However, a second, perhaps more enigmatic group consists of elite and amateur athletes who exhibit clear signs of EIB but lack any underlying clinical asthma. For this demographic, researchers have proposed numerous potential mechanisms, focusing heavily on environmental exposure and the physiological stress of hyperventilation. A critical focal point of recent studies has been the specific environments in which children and adolescents train. Research analyzing the type of sport played by athletic youth has revealed a significant disparity in EIB prevalence based on the venue. Indoor sports have been associated with a markedly higher risk of pulmonary complications. This elevated risk is largely attributed to poor indoor air quality, where particulate pollution, chemical irritants, and allergens become trapped and concentrated in buildings that are not cleaned or ventilated regularly.

The statistical difference is striking. Studies have demonstrated that while approximately 21% of outdoor athletes were diagnosed with EIB, a staggering 47% of athletes training in indoor facilities developed the condition (28). Among the most concerning indoor environmental factors is the presence of mold. In damp, poorly ventilated athletic facilities, mold spores accumulate rapidly. The inhalation of these spores can be highly dangerous because, for many individuals, mold acts as a remarkably strong allergen and irritant. It directly damages the airway epithelium and triggers a profound inflammatory cascade, leading to airway constriction even in non-asthmatic youths (31).

Furthermore, the duration and intensity of the sport play a crucial role. High-ventilation indoor sports, such as swimming (where athletes inhale chlorine derivatives like trichloramines) or ice hockey (where ice resurfacing machines release ultrafine particulate matter and nitrogen dioxide), create a "toxic soup" for the lungs (32). When athletes breathe in these trapped pollutants at high volumes, the osmotic and thermal balance of the airways is disrupted, leading to the release of inflammatory mediators like histamine and leukotrienes, ultimately resulting in the narrowing of the bronchi.

## **2.7 Clinical symptoms and diagnostic procedures of EIB**

While the diagnostic framework for chronic asthma is already well-established globally, Exercise-Induced Bronchoconstriction (EIB) as a standalone condition remains

surprisingly underrecognized by many physicians and healthcare professionals in the sports medicine field. The clinical symptoms, which are remarkably similar in both conditions, typically include audible wheezing, persistent post-exercise coughing, severe dyspnea (shortness of breath), and a pronounced sensation of chest tightness.

However, the primary differentiator between the two respiratory profiles is the aspect of baseline pulmonary function and symptom chronobiology. In pure EIB, a patient's resting lung function is completely normal, and airway constriction is exclusively triggered by vigorous physical exertion typically peaking 5 to 15 minutes after the exercise ceases. In contrast, clinical asthma involves chronic, baseline airway inflammation and hyperresponsiveness that can be triggered by various non-exercise stimuli at any time of day (5).

Because pure EIB only manifests under specific physical stressors, it is widely reported that many patients remain undiagnosed. Although widespread screening programs are unlikely to be implemented due to their prohibitive costs and limited diagnostic specificity, targeted testing for high-risk groups remains essential (33).

To diagnose EIB according to current medical standards, physicians primarily use exercise challenge tests combined with spirometry (34). However, in predisposed groups like patients with asthma, new research shows that measuring Fractional exhaled Nitric Oxide (FeNO) can be used to predict the odds of EIB in asthmatic schoolchildren, completely independently of other asthma severity markers and the intensity of ongoing anti-asthma therapy (35).

Furthermore, mapping these biomarkers allows medical professionals to customize specific pharmacological interventions, distinguishing between the need for daily chronic asthma treatments (like inhaled corticosteroids) versus targeted, pre-exercise prophylaxis for isolated EIB.

### **3. Conclusion**

It is estimated that asthma affects between 8.8% and 11.3% of the global population, and its prevalence is on the rise, particularly in highly industrialised and urbanised areas. It is therefore no surprise that EIB is now considered the most common chronic condition among elite athletes. This health problem has a significant negative impact on the respiratory system, manifesting in a range of symptoms such as coughing, shortness of breath, wheezing, chest

tightness and increased fatigue, but it also affects mental well-being by intensifying feelings of fear, frustration and even depression. Together, these factors can noticeably reduce sporting performance. This problem is particularly evident in disciplines endurance sports, such as winter sports, swimming or cycling. The pathophysiology of exercise-induced bronchoconstriction is complex due to the number of factors that often co-occur. One of the most important is the hyperosmotic theory, which explains that during exercise, water is lost from the surface of the airways. This phenomenon is also exacerbated by hyperventilation, which causes the airways to dry out and cool through evaporation, and such a rapid loss of water leads to the release of inflammatory mediators that trigger asthma symptoms. However, effective solutions for treating or preventing EIB are known. These include, among others, the use of preparations that inhibit the action of the enzyme 5-lipoxygenase. A low-salt diet or supplementation with vitamin C and omega-3 fatty acids.

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