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Exercise Induced Bronchoconstriction - An Overview

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Abstract

Introduction

Asthma and exercise-induced bronchoconstriction (EIB) are common respiratory conditions in athletes, presenting unique challenges due to the physiological demands of high-intensity training and environmental exposures. While asthma is characterized by airway hyperresponsiveness and inflammation, EIB specifically refers to transient airway narrowing triggered by physical exertion. Both conditions can significantly impact athletic performance and quality of life if not properly managed. This article explores the mechanisms underlying asthma and EIB in athletes, outlines diagnostic criteria and techniques, and discusses evidence-based management strategies. By addressing these conditions comprehensively, athletes can achieve optimal control, sustain performance, and mitigate long-term respiratory health risks.

Exercise-induced bronchoconstriction (EIB) is a common condition among athletes, particularly those involved in endurance sports, and can significantly impact their performance and quality of life. The underlying mechanisms of EIB remain complex and are influenced by various factors, including airway cooling, dehydration, increased exposure to allergens and pollutants, and intense physical exertion. The inflammatory responses in the airways of athletes with asthma are often unique, with increased airway sensitivity and reactivity. Factors such as increased ventilation, pollutants, allergens, and airway remodeling contribute to the high incidence of EIB in athletes.

The diagnosis of asthma and EIB relies on clinical symptoms, peak expiratory flow measurements, and bronchoprovocation tests, including exercise challenge testing and methacholine challenges. These methods help establish airway hyperresponsiveness and assess the severity of bronchoconstriction. Diagnosis can be complicated by the need for multiple tests, as symptoms and airway responsiveness may fluctuate with training intensity.

Treatment and management strategies for EIB in athletes are multifaceted and include both pharmacological and non-pharmacological approaches. Non-pharmacological strategies emphasize asthma education, environmental control, and exercise modification. Pharmacological interventions commonly include inhaled glucocorticoids, β2-agonists, leukotriene modifiers, and mast cell stabilizers. These treatments aim to manage symptoms, improve lung function, and reduce the occurrence of bronchoconstriction. Successful management requires a coordinated approach, involving healthcare providers, sports medicine professionals, and coaches, to ensure proper diagnosis, treatment adherence, and the continued participation of athletes in their chosen sports.

Methods

This article bases on relevant papers regarding exercise-induced bronchoconstriction found on PubMed and Google Schoolar. The keywords used were: 'exercise-induced bronchoconstriction', 'EIB', 'asthma in athletes', 'exercise-induced asthma', 'EIA'. Authors reference papers written from year 2000 onwards, with main focus put on articles written from 2015 onwards.

Keywords: exercise-induced bronchoconstriction, EIB, exercise-induced asthma, EIA, asthma, bronchoconstriction, exercise

WHAT IS EXERCISE INDUCED BRONCHOCONSTRICTION?

Asthma is an extremely varied disease characterized by shortness of breath, wheezing, chest tightness and coughing caused by chronic airway inflammation that leads to fluctuating expiratory airflow limitation. [1] Although these symptoms are typical in patients with asthma, they can also occur in people without such diagnosis. [2 -7] In professional and non-professional athletes physical activity can lead to *transient* symptoms resembling an asthma attack due to post-exercise bronchoconstriction. [2] This occurrence can be linked to different stimuli and unique environment that engaging in sports presents - it is especially observed in endurance disciplines that facilitate bronchial hyperresponsiveness. This distinct form of airway hyperresponsiveness is defined as exercise induced bronchoconstriction (EIB). [7] It has been observed that prevalence of asthma in professional athletes is higher than in general population - ranging between 23% to 55%. [8] Prevalence of EIB is naturally higher in athletes with values ranging between 30% to 70% [9], showing that the amount of training and the occurrence rate of exercise-induced bronchial symptoms are directly related.

Even though the occurrence varies between ethnicities and age groups, it affects approximately 339 million people globally, rates ranging between 4% to 10% in Western countries. [1] The data variation concerning the prevalence can be explained by the difference in used terminology. Exercise induced bronchoconstriction (EIB) refers to the acute narrowing of airways, accompanied by asthma-like symptoms or not, resulting from physical exercise. The term exercise induced asthma (EIA) is used to define said symptoms in a patient with already diagnosed asthma, with symptoms occurring not only after physical activity. [9] The data variation can also be associated with the fact that it simply goes unreported, as the recent studies confirm the higher presence of EIA/EIB that is still underdiagnosed and undertreated [7]. The symptoms of EIB/EIA still often go unrecognized and blamed on lack of physical fitness. Those affected will avoid exercising and blame their symptoms on lack of endurance. Some athletes, coaches and parents of children affected by EIA/EIB may impose restrictions in fear of symptoms that follow after physical activity [2].

In today’s literature the terms „EIA” and „EIB” are still not so distinctly differentiated and often used interchangeably. The term EIA should give way to the distinction between EIB with asthma (EIBA) and EIB without asthma (EIBwA). In that instance EIBA refers to bronchial constriction after physical activity in patients that present with asthma symptoms, while EIBwA relates to bronchial constriction in individuals without other asthma siymptoms. [10] In this article the exercise-induced asthma-like symptoms should be referred to further as exercise induced bronchoconstriction (EIB) or otherwise if stated, as the majority of data available still doesn’t differentiate so thoroughly.

SYMPTOMS

Despite the fact that prevalence of asthma and EIB in athletes is high, reports of exercise induced respiratory symptoms are shown to be even higher in recent studies. This suggests that asthma and EIB are either underdiagnosed or that other conditions that mimic asthma are assigned to the correct diagnosis of EIB or asthma. [11] Study by Burnett et al. shows that in 47% of athletes that report exercise-induced respiratory symptoms, 33% did not have a prior history of EIB or asthma diagnosis. [12]

Clinical symptoms of EIB can range from moderate to severe. This can include: the feeling of chest tightness, chest pain, shortness of breath, dyspnea, coughing, wheezing, excessive mucus production and feeling of 'itching' or 'scratching' sensation in the chest. This usually occurs within 3 to 15 minutes after 5 to 8 minutes of high-intensity aerobic training and resolves within 20 to 90 minutes [13-17] . After recovery, a refractory period can be observed that lasts between 40 minutes to 3 hours, when further exercise causes less bronchoconstriction [18]. Symptoms may occur more often in specific conditions, such as environments with dry and cold air or with high concentrations of respiratory irritants. Also some patients may present mild symptoms, leading to EIB being underdiagnosed. [16]

When considering symptoms of EIB it is crucial to mention possible differential diagnoses, as exercise induced bronchoconstriction may not be easily diagnosed purely based on clinical symptoms. Symptoms of chest tightness, coughing and dyspnea can be interpreted as different pathology in the respiratory, cardiovascular and gastrointestinal system. [13] [16]

Nasal Airways

Possible other diagnoses may be:

- allergic rhinitis
- exercise induced rhinosinusitis
- upper respiratory cough infection
- upper airway cough syndrome
- anatomic abnormalities

Nasal airways have an important role in supplying air to the respiratory system by filtering, humidifying and regulating nasal resistance, and therefore conditions in nasal airways can be comorbid with EIB. [16] [19-20]

Pharynx and Larynx

The differential may include exercise-induced laryngeal obstruction (EILO). Patients with EILO present similarly to individuals with EIB, however mechanism, diagnosis and treatment is entirely different. [13] [16]

Lower Airways

Concerning the lower airways, the differential diagnoses may be: asthma and respiratory tract infection. Less common causes include edema (especially in immersion or high-altitude sports) and saltwater aspirations syndrome. Patients should also be asked about smoking. [3] [7] [13] [16] [19]

Cardiac

Cardiac causes of exertional dyspnea should be thoroughly investigated, especially in children. [21]

Gastrointestinal

Gastroesophageal Reflux Disease could be a cause of respiratory tract irritation leading to coughing and chest pains. [16]

CAUSES AND MECHANISM

The mechanism of EIB has not been established with certainty. [7] The prevalence rates vary depending on the sport, training conditions, and genetic factors. While physical exercise is a known trigger for asthma, it can also paradoxically enhance lung function and reduce the severity of exercise-induced bronchoconstriction (EIB). However, asthma phenotypes in athletes are diverse, leading to different responses to treatment and challenges in management. Key factors in athletes include increased airway sensitivity, exposure to allergens and pollutants, and temperature fluctuations. Elite athletes often show unique inflammatory responses and heightened airway reactivity, influenced by the type of sport, training intensity, and environmental factors. Sports like swimming, which involve exposure to chlorinated water, pose a higher risk for EIB. Exercise itself remains a major trigger for asthma, and the combination of rigorous training, allergen exposure, and inhalation of irritants in specific

settings contributes to the higher incidence of asthma in athletes. Immune system responses, lung function changes, and individual differences all play a role in EIB among athletes. [1]
Airway cooling resulting from inspired air, as well as, and post-exercise airway warming have been proposed as mechanisms. Airway dehydration as a result of increased ventilation, and therefore augmented osmolarity of the airway-lining fluid, has been proposed as a main stimulus. [22] During physical exercise cardiac output increases, as well as, minute ventilation, which is reported to reach 200 liters per minute in high-level athletes. [23] At such high minute ventilations, intense heat and water exchange takes place in the respiratory system. In addition, there is an increased penetration of pollutants and allergens, such as chloramines from chlorinated water, and particulate matter into the lower airways. This is assumed to trigger the release of histamine, leukotrienes, prostaglandins and cysteinyl from airway inflammatory cells, which then leads to smooth-muscle contraction and edema. Moreover, the previously mentioned stress to the airways may be involved in the airway remodelling in the athletes. [3] [24] [25] It is thought that the acute response to the physical exercise, which results in osmotic and mechanical stress to the airways, can worsen this process and contribute to exercise-induced bronchoconstriction. [26]
Additionally, both osmotic and mechanical stress on the airways may not only influence the immediate exercise response but could also play a role in airway remodeling in athletes, likely through their impact on airway epithelial cells. Moreover, intense training periods may lead to temporary immune suppression, increasing vulnerability to respiratory infections, especially viral ones, which can heighten the airway response to exercise and negatively affect asthma management. [6] [22] [25]
Athletes with asthma often exhibit a neutrophilic inflammatory phenotype in the airways. [22] Tumor necrosis factor-alpha (TNF-α) is thought to contribute to the inflammatory pathways leading to airway hyperresponsiveness (AHR), possibly through its effect on the contractility of airway smooth muscle cells. [27] In a study by Toennesen et al. observed that of 57 elite summer-sport athletes, 32% had asthma, and they found that methacholine responsiveness was higher with increased serum TNF-α levels. However, serum levels of C-reactive protein, interleukin-6 (IL-6), IL-8, and TNF-α were similar between asthmatic and non-asthmatic athletes. [28] In contrast, Kennedy et al. found a significant increase in sputum eosinophils and lymphocytes in 18 Canadian elite female cross-country skiers during the competitive season compared to their training period. The study suggested that female athletes may be at

greater risk for airway inflammation and AHR than males, possibly due to smaller lungs and airways, which could lead to higher airway resistance and shear stress, although it was unclear why mostly eosinophils were increased. [29]

In terms of parasympathetic influences, Langdeau et al. previously proposed that cholinergic tone, assessed through heart rate variability, plays a modulatory role in AHR in athletes. [30] More recently, Stang et al. observed that in elite Norwegian cross-country skiers and swimmers, both asthmatic and non-asthmatic, a higher cardiac vagal index was associated with increased AHR, particularly in swimmers, supporting the idea that elevated parasympathetic tone may enhance airway reactivity. [31]

The role of the airway epithelium has also been studied. Bougault et al. showed that elite swimmers had higher bronchial epithelial cell counts in their sputum compared to non-athletes, suggesting epithelial shedding in these athletes. [32] Seys et al. found that elite swimmers and indoor athletes had higher serum levels of Clara cell protein-16, a marker of epithelial injury, compared to nonathletes without asthma, indicating that exercise combined with exposure to chlorination by-products may cause more epithelial damage, potentially contributing to airway remodeling in swimmers. [33]

Heffler et al. proposed that vitamin D deficiency, common in winter, might lead to laryngeal muscle weakness and laryngospasm during exercise in young athletes, possibly due to disrupted calcium homeostasis, although this remains speculative. Another characteristic of asthma is increased bronchial vascularization, which leads to higher blood flow and basal exhaled breath temperature (EBT) in asthmatic individuals. [34]

Asthma is often associated with increased bronchial vascularization, which leads to higher blood flow and, consequently, elevated exhaled breath temperature (EBT) compared to healthy individuals. For instance, a study by Couto et al. observed that after a training session, 27 adolescent elite swimmers showed an increase in EBT, reflecting heat loss during physical exertion. However, there was no significant difference in EBT between asthmatic and non-asthmatic swimmers, suggesting that asthma may not have a distinct effect on this parameter in swimmers. [35]

Recent studies emphasize that asthma in elite athletes has well defined features, resembling an occupational condition caused or triggered by intense, repeated exercise in specific environments. It is stressed that among athletes, elite swimmers are particularly prone to developing airway dysfunction. According to Lomax, at least four years of competitive swimming, involving over 10 hours of training per week, is typically necessary to induce airway dysfunction in otherwise healthy elite swimmers. Disinfection methods other than chlorine, such as copper, silver or ozone, appear to be less harmful to the airways, though further longitudinal studies are needed to assess their long-term effects. [36]

DIAGNOSIS

Asthma is diagnosed based on a patient's recurring respiratory symptoms and evidence of airway hyperresponsiveness (AHR). [36]

In athletes, asthma can be diagnosed based on a history of characteristic symptoms and documentation of variable airflow limitation, which can be assessed through bronchodilator reversibility testing or bronchoprovocation tests. However, respiratory symptoms alone have limited predictive value for diagnosing asthma or EIB - the presence of variable airway obstruction is required for diagnosis in all patients. [6] [25] In some athletes, such as swimmers, expiratory flows can be supranormal (e.g., >120% of predicted values), so maximum achievable expiratory flows should always be documented. In relation to this, a diagnosis of asthma or EIB should be based on more than 10% diurnal variability in peak expiratory flow (PEF) over two weeks, or more than 12% variability in forced expiratory volume in 1 second (FEV1) over time or after 4 weeks of treatment. The presence of airway obstruction can also be demonstrated by a greater than 12% change in FEV1 after inhaling a β2-agonist. If baseline airway caliber is normal, airway hyperresponsiveness can be assessed using bronchoprovocation tests, which include direct challenges (e.g. inhaled methacholine) and indirect tests such as eucapnic voluntary hyperpnea (especially for athletes), hyperosmolar tests with saline or mannitol, and exercise tests. [13] [22] [37] [38]

American Thoracic Society (ATS) recommends conducting exercise challenge testing in a controlled dry environment. Key testing parameters outlined by the ATS include ventilation levels, heart rate, duration at maximum capacity, and medications to avoid before testing, such as caffeine. Patients should refrain from entering the refractory period before testing. Spirometry measurements, specifically FEV1, should be taken during exercise at 5, 10, 15, and 30 minutes. FEV1 is reliable and is the ATS-recommended measure for diagnosing exercise-induced bronchoconstriction (EIB). [13] A decrease in FEV1 of 10% or more is diagnostic for EIB, with mild defined as 10-25%, moderate as 25-50%, and severe as 50% or more. [13] [14] Some labs use a 15% reduction as the threshold for more specific diagnosis. Due to a reproducibility rate of 76%, some patients may need multiple exercise tests to confirm the diagnosis. [13]

Some smaller studies suggest that fractional excretion of nitric oxide (FENO) could replace FEV1 for diagnosing and assessing the severity of EIB, offering an alternative to spirometry-based FEV1 percent change. FENO testing can be used alongside direct or indirect methods and is easier to perform in younger children. FENO measures the T-helper cell type 2 (Th2) inflammatory response, in contrast to airway hyperresponsiveness, and may be more effective at distinguishing EIB from other etiology of symptoms. Suggested diagnostic cut-off values for FENO range from 27 to 46 ppb, with levels above 46 ppb being 100% specific. [39-41]

However, athletes may respond to only one type of test, and airway responsiveness may return to normal after a few weeks of reduced training. Thus, multiple tests may be necessary, ideally during periods of intense training. It's important to differentiate asthma from other conditions mentioned in the previous chapter, which can mimic asthma in athletes. These conditions should be considered if test results are inconclusive or if the response to treatment is inadequate. [7] [32]

TREATMENT, MANAGEMENT AND PREVENTION

The objectives of asthma management include achieving and sustaining control, improving pulmonary function, and reducing risk factors for acute episodes. [42] It should place importance on education, self-management and early identification of and treatment of symptoms with adequate therapy. [36]

Non-pharmacological treatment

Education on asthma self-management is essential for all individuals with asthma. This should cover topics like managing environmental factors, ensuring proper inhaler technique, and using an asthma action plan to handle flare-ups, along with regular follow-up care. [42] While face masks can help limit the impact of cold air during winter sports or reduce exposure to airborne pollutants, they are often not well tolerated. [43] A pre-exercise warm-up, consisting of low or variable-intensity movements, can help reduce bronchoconstriction in more than half of athletes. [44] This effect is due to a 'refractory period' caused by protective prostaglandins and the reduced responsiveness of airway smooth muscle to constricting mediators, which lasts for about two hours, offering a temporary relief from exercise-induced constriction. [44] [45] Treatment should also address any accompanying conditions like gastroesophageal reflux, rhinitis, or exercise-induced laryngeal obstruction. In the case of laryngeal obstruction, targeted breathing exercises and avoiding irritants are effective approaches. [7] Although it's ideal for athletes to steer clear of very cold, dry air or times of high allergen or pollutant exposure, this is often difficult. Whenever possible, it is advisable to avoid exercising near busy streets or during peak allergen seasons. [46] [47] Additionally, improving ventilation in swimming pools, reducing chloramine formation in chlorinated pools, and minimizing exposure to indoor and outdoor pollutants like ozone, particulate matter, and nitrogen oxides, should be promoted. [46] [48]

Physical activity often triggers asthma symptoms, leading some individuals to avoid exercise altogether. Ironically, this avoidance worsens their condition by perpetuating a cycle of reduced fitness and deconditioned skeletal muscles. Research consistently shows that engaging in regular exercise can alleviate asthma symptoms - by enhancing endurance, improving lung function, lowering airway inflammation, and boosting overall quality of life. [1] [14]

Cochrane review has documented that exercise improves EIB severity and reduces airway inflammation in people with asthma and EIB. Individuals with both asthma and EIB appear to encounter unique challenges compared to those managing asthma alone. The emergence of symptoms during exercise frequently discourages regular physical activity, further diminishing their quality of life and reinforcing this negative cycle. [16]

An important note to factor in when considering EIB is the bodyweight of a patient experiencing EIB. Decreasing bodyweight and increasing physical endurance is generally helpful in alleviating EIB symptoms and reduces the probability of possible future episodes. [16]

Another treatment approach includes the patient's perception of symptoms. It focuses on breathing exercises - including yoga and supervised breathing training - to divert attention from respiratory symptoms. In some small studies it has been shown that such approach decreases symptoms, reduces medication use and decreases anxiety and depression associated with EIB. [49]

Pharmacological treatment

Asthma treatment in athletes relies heavily on inhaled glucocorticoids, just as it does for non-athletes. [25] [42] These medications are sanctioned for use in sports and are fundamental to controlling symptoms. Nevertheless, athletes often underutilize them while over-relying on β2-agonists. [50] If low doses of inhaled glucocorticoids fail to achieve asthmatic symptoms control, combining them with a long-acting β2-agonist should be considered. [7] Leukotriene modifiers (LTRA), known for minimizing EIB caused by pollutants, also offer a beneficial alternative. [2] [51] [52] Although cromolyn sodium and nedocromil sodium have also been shown to protect against EIB, β2-agonists generally outperform them. Medications like nasal glucocorticoids and antihistamines may help manage rhinitis symptoms associated with asthma, but they do not address EIB directly. Immunotherapy shows limited benefit for asthma overall and remains underexplored in athletic populations. [42]

Inhaled β2-agonists, whether used by athletes with or without asthma, do not enhance physical performance. Short-acting inhaled β2-agonists, however, remain highly effective for symptom relief and can be taken before exercise to prevent bronchoconstriction, typically within 5–10 minutes of activity. That said, frequent or excessive use may heighten airway reactivity to irritants, reduce protective effects during exercise, and cause tolerance due to β2-receptor desensitization. [53] For those requiring additional control, long-acting β2-agonists may be combined with inhaled glucocorticoids, but it is important to note that long-acting β2-agonists should never be used in isolation. [42]

The most common strategy for athletes who train regularly and have asthma or EIB are often advised to follow a daily regimen of inhaled glucocorticoids, complemented by occasional use of short-acting β2-agonists before vigorous physical activity. LTRA offer another option for routine management and may provide enhanced protection when combined with inhaled glucocorticoids. [51] However, achieving full asthma control in athletes can remain challenging. Factors such as heightened airway responsiveness, misdiagnosis, comorbid conditions, poor adherence to prescribed treatments, improper inhaler use, or resistant asthma phenotypes may contribute to suboptimal outcomes. [7]

Mast Cell stabilizing agents (MCSA) have been shown to help with EIB in athletes, as mast cell degranulation plays a key role in EIB pathology. However, there is no additional benefit when MCSA is combined with short acting β2-agonist, and are also less effective than the latter. [13]

Short-acting muscarinic antagonists (SAMA) are weakly recommended, with low-quality evidence. They are less effective than SABA, however SAMA can be used in combination when a tolerance against SABA develops. [13] [54]

Antihistamines may be considered in patients with underlying allergies that can cause or exacerbate EIB symptoms. [13]

Caffeine may help prevent bronchoconstriction, reduce ventilatory dead space, and alleviate exercise-induced hypoxemia and fatigue in respiratory muscles when administered before physical activity. [49]

Healthcare team

Effective management of EIB requires coordinated care among primary care providers, pulmonologists, ENT specialists, sports medicine professionals, and coaches to ensure accurate diagnosis and appropriate treatment. Coaches play a crucial role in identifying athletes who show signs of symptoms during practice or who consider quitting due to poor fitness levels, which could indicate EIB. Educating coaches is essential for ensuring they understand the importance of measures like face protection against cold, dry air, pollutants, allergens, and particulate matter during training. Coaches can collaborate with school administrations to ensure the safety of practice locations and swimming pool conditions.

Primary care sports medicine providers are often the first to assess athletes presenting with symptoms, but proper diagnostic testing is needed since clinical symptoms alone are neither sensitive nor specific, and some patients may not show symptoms. A comprehensive differential diagnosis should consider all aspects of the airway, with referrals to otolaryngologists when necessary. Coordination with pulmonology may be required, especially for athletes with difficult-to-manage asthma. Effective communication and teamwork across healthcare providers can result in the correct diagnosis, treatment adherence, and optimal control of bronchoconstriction, allowing athletes to continue their activities without limitation. [16]

CONCLUSIONS

Asthma and exercise-induced bronchoconstriction (EIB) present challenges for athletes but can be effectively managed with proper care. A combination of pharmacological treatments, such as inhaled glucocorticoids and β2-agonists, alongside non-pharmacological strategies like warm-ups, breathing exercises, and environmental adjustments, helps minimize symptoms and improve performance. Collaboration among healthcare providers, coaches, and athletes is essential for accurate diagnosis, personalized treatment, and adherence to management plans. Regular exercise, when well-managed, can even alleviate asthma symptoms. With the right approach, athletes can overcome respiratory challenges, maintain active lifestyles, and achieve success in their chosen sports without compromising their health or well-being.

Disclosure

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