

Management of Intermittent and Persistent Asthma in Adolescent and High School Athletes



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Learning objectives:

1. To understand the mechanisms of exercise-induced bronchoconstriction (EIB) and of exercise-induced bronchoconstriction with asthma (EIBa).
2. To identify low-, medium-, and high-asthmogenic sports.
3. To become familiar with the correct diagnostic workup for asthma in adolescents and high school athletes.
4. To understand how to manage intermittent and persistent asthma in adolescents and high school athletes.

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Asthma is the most common chronic condition during childhood and adolescence, affecting an estimated 8% of children and youngsters below 18 years in the United States and the United Kingdom. In adolescent athletes, asthma-like symptoms may represent a common consequence of regular sport practice. Asthma in young athletes poses several challenges, including the

ambiguity of definitions and diagnosis of asthma resulting from exercise-induced symptoms, the best pharmacological treatments, and the nonpharmacological options for the management of disease and the challenges inherent to this age group. At a time when the regular practice of sports is increasingly being recommended for a healthy living, the

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Abbreviations used

BHR-Bronchial hyperresponsiveness
EIA-Exercise-induced asthma
EIB-Exercise-induced bronchoconstriction
EIBa-Exercise-induced bronchoconstriction with asthma
EVH-Eucapnic voluntary hyperpnea
QOL-Quality of life
SABA-Short-acting β_2 -agonist

support network around the young athletes is crucial to reduce the impact of asthma on their physical and emotional well-being. In this review, we examine the main issues around the definitions and clinical differentiations of asthma in young sport athletes. We discuss best practice approaches to improve the adherence to the clinical management, including nonpharmacological strategies directed at the family and trainers of athlete adolescents. © 2020 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2020;8:2166-81)

Key words: Asthma; EIB; EIBa; Young; Adolescent; Sports; Athlete; Clinical management

INTRODUCTION

Asthma is the most common noncommunicable disease in childhood and adolescence worldwide,¹ with an estimated 8% to 9% of children and youngsters below 18 years in high-income countries, and an increasing proportion of children in low- and middle-income countries being affected by the disease.² Recognized as a multifactorial disease, a complex range of environmental, host/lifestyle, and genetic determinants can influence the risk and severity of asthma in children and adolescents.³

The practice of regular physical activity and exercise is widely recommended for a healthy lifestyle, because it is beneficial for the cardiorespiratory system, improves psychological functioning, and favors socialization. According to the US Centers for Disease Control and Prevention, nearly 30 million people regularly participate in youth sports in the United States; 37.8% of them participate in a team sport.⁴ Worldwide, it is estimated that between 20% and 30% of adolescents practice sports.⁵

However, exercise is also a well-known trigger for asthma symptoms, and 35% of children with asthma will report asthma symptoms during exercise.⁶ On the other hand, exercise has been proven as beneficial for patients with asthma. Recent evidence from controlled trials that implemented a physical training program intervention in children and adolescents with asthma (aged 6-18 years) showed that exercise, beside the beneficial effect on cardiorespiratory fitness outcomes, can reduce exercise-induced bronchoconstriction (EIB) in some cases.⁷ Furthermore, high levels of fitness have been associated with a lower prevalence of asthma symptoms in children who regularly exercise.⁸

In this article, we discuss the clinical management of asthma in adolescent and high school athletes and review the role of respiratory symptoms and other outcome responses observed in children who exercise. Because our focus is on young athletes, we will not discuss studies that only reported asthma management in adolescents, or those that only used EIB as outcome in adolescents who were not enrolled or participated in any regular sports.

EIB is defined as a transient narrowing of the lower airways after exercise in the presence or absence of clinically recognized asthma.⁹ The terms EIB and exercise-induced asthma (EIA) have been used for many years interchangeably.¹⁰ EIA is no longer a recommended term, however, because it could incorrectly suggest that exercise causes an asthma attack (rather than exacerbates or triggers an asthma attack); it is therefore preferable to use the term exercise-induced bronchoconstriction with asthma (EIBa)⁹ when referring to patients with an underlying asthma and symptoms induced by exercise, and EIB for patients without an underlying asthma who experience symptoms only when exercising.

ASTHMA IN THE ATHLETE

An estimated 75% to 80% of untreated patients with asthma may experience an asthma attack provoked by exercise; however, up to 10% of otherwise healthy individuals may also have a reduction in lung function during exercise, in particular children and adolescents.¹¹

In adolescent athletes, the prevalence of asthma is reported to be between 12% and 38%.^{12,13} In the Oslo birth cohort study, 36.7% of 10-year-old children showed EIB, and 8.6% of the entire population-based cohort showed a positive EIB test result.¹⁴ However, a correct estimate of the prevalence of EIB and EIBa is challenging,¹⁵ due to a lack of uniformity in definition, as previously stated, or study methods (eg, self-reported questionnaires, antidoping applications for antiasthmatic drug use, and spirometry with bronchoreversibility test).

Table I summarizes the differences between several studies of athletes practicing different sports.

Mechanisms and clinical characteristics

An exercise-related bronchoconstrictive response usually occurs after a minimum of 5 to 8 minutes of continuous, high-intensity exercise, and reduction in lung function or symptoms are usually observed 2 to 10 minutes after it.

Symptoms are usually observed after (or, more rarely, during²⁹) exercise, and do not differ from those observed in “common” asthma, peaking at around 10 to 15 minutes. Symptoms disappear spontaneously after 30 to 60 minutes, after which they are followed by a 2- to 3-hour period during which renewed exertion generally does not trigger any other symptom, or at most very slight symptoms (the so-called refractory period).³⁰

How does exercise cause bronchoconstriction?

Classically, 2 mechanisms are behind EIB, both connected to the marked increase in ventilation during sports activity. The “osmolar” hypothesis is linked to the increased water loss through respiration and the consequent increase in osmolarity of the fluid overlying the bronchial mucosa, allowing water to move extracellularly and consequently shrinking the bronchial cells, with an increase in intracellular ion concentration and increased release of preformed and newly-formed inflammatory mediators by mast cells, eosinophils, and neutrophils, causing a bronchial inflammatory response.¹⁵

The “vascular” or “thermal” hypothesis refers to the heat loss at a bronchial level due to an increased ventilation and due to the oral breathing pattern that may occur under high-intensity exercise, bypassing the nose, which normally acts as a rebreathing organ, humidifying and warming the inspired air. Cooling of the airways activates the parasympathetic system with consequent

TABLE I. Studies investigating sport practice in young athletes, and prevalence and clinical management of EIB/EiBa

First author (year)	Study and participant characteristics	Sport	Asthma outcome	Main results
Feinstein ¹⁶ (1996)	Screening and diagnostic testing using convenience sample n = 52 black males (4 excluded); 14-18 y	Football	- EIA ($\geq 15\%$ decrease in FEV₁ or peak expiratory flow rate [PEFR] after completing an exercise challenge) - Clinical management: β2-agonist	17 athletes had $\geq 15\%$ in PEFR and 9 had $\geq 15\%$ in FEV ₁ ; significant differences in personal history of asthma between normal and abnormal PFT results ($P < .05$)
Hammerman ¹⁷ (2002)	Observational; data and screening collected during the athlete's participation in sports between 1998 and 2000 (18 mo) n = 801 student athletes (63% males and 93% Caucasian); 13-18 y; 10 schools located in rural Westmoreland County, Pittsburgh, Pa	Football, baseball, soccer, track, lacrosse, field hockey, and volleyball	- EIA (decrease of $\geq 15\%$ in PEFR after free running test) - Asthma (self-reported)	46 athletes had asthma or EIA; 49 from the remaining 755 had undiagnosed asthma; 85% of the known athletes with asthma had decrease of $>15\%$ in PEFR
Kukafka ¹⁸ (1998)	Cross-sectional; community high school athletic facilities and pilot RCT between 1995 and 1996 n = 238 male athletes (92 European-Americans, 140 African Americans, 5 Hispanics, and 1 Native American); mean age 16 ± 1 y; from 9 high schools in Philadelphia Pilot RCT: 15 athletes with EIB (n treated = 8)	Football	- EIB: decrease of $\geq 15\%$ in PEF - Clinical management for pilot RCT: albuterol	24 athletes (10%) reported history of treated asthma Prevalence of EIB: 9% For pilot RCT: placebo-treated showed $16\% \pm 5\%$ fall in PEF on initial testing and a $14\% \pm 3\%$ drop with placebo vs albuterol-treated athletes showed $15\% \pm 6\%$ fall in PEF at initial testing to an increase in PEF of $6\% \pm 9\%$ from baseline
Lennelöv ¹⁹ (2019)	Postal questionnaire survey addressing adolescent skiers from all regions participating in the Swedish National Cross-country Championship together with a random population-based reference sample of adolescents of similar ages Athletes: n = 331 (49% females) Swedish competitive cross-country skiers in early adolescence; age: 12-15 y Reference group: n = 1000 random population-based sample of adolescents; age 13-14 y	Ski	- Self-reported asthma (physician-diagnosed), current wheezing, wheezing without a common cold, and exercise-induced wheezing - Clinical management: SABAs/LABAs, ICSs, ICSs + LABA, or other medication, ICSs, ICSs + LABA or other medications	Prevalence of self-reported asthma and wheezing significantly different: 23% and 25%, respectively, among skiers vs 12% and 14%; no significant differences for the usage of asthma medications nor the level of asthma control between skiers and the reference group

Lumme ²⁰ (2003)	Case-control study; athletes recruited from 3 Finnish junior ice hockey teams between 2001 and 2002; control subjects recruited from 2 courses of medical students randomly selected from the University of Helsinki n = 88 male highly trained ice hockey players; mean age: 18.1 ± 0.9 y n = 47 control subjects (36 males); mean age: 26.7 ± 6.0 y	Ice hockey	• Asthma (self-reported) • Asthma (physician-diagnosed); increased bronchial responsiveness: dose of histamine that caused a 15% fall in FEV₁ ≤ 1.6 mg; current asthma: increased BHR, together with at least 1 exercise-induced bronchial symptom occurring monthly during the last year • Total asthma (current asthma or asthma diagnosed previously by a physician; sputum eosinophilia: sputum differential eosinophil count of >2%) Clinical management: ICS and SABA	Prevalence of BHR, current asthma, and total asthma in athletes and controls: 23.9% and 10.6%, 14.8% and 2.1%, and 21.6% and 4.2%, respectively The differential cell counts of eosinophils (2.6% vs 0.2%) and neutrophils (80.9% vs 29.9%) in the sputum samples of the ice hockey players were significantly higher than those of the control subjects
Mannix ¹² (2004)	Observational n = 79 high school athletes from Franklin Central High School (46 males); mean age: 16.2 ± 1.2 y	Not specified	• Airways hyperresponsiveness (AHR) (decrease in FEV₁ of ≥10%; FEF₂₅₋₇₅ of ≥20%; and/or PEF of ≥25%)	30 of 79 tested positive for AHR
Norqvist ²¹ (2015)	Prospective 5-y cohort study using postal questionnaires between 2011 and 2015; Sweden 4 groups: -Group 1: n = 214 (49% females) pupils at the Swedish national elite sport schools located in 7 cities in the middle and northern parts of Sweden; age: 15-19 y -Group 2: n = 26 (41% females) members of the Swedish junior and senior national teams in cross-country skiing, biathlon, ski orienteering, and orienteering; age: 18-34 y -Group 3: n = 53 (49% females) students at Swedish ski universities where elite skiers with exceptional merits may combine a higher education with an elite athlete career -Group 4: n = 71 top (53% females) Swedish orienteers, aged 20-30 y -Group 5: n = 66 (30% females) former Olympic athletes; age: 41-94 y	Cross-country skiing, biathlon, and ski orienteering	• Self-reported physician-diagnosed asthma • Use of asthma medication • Asthma-related symptoms	Prevalence of reported asthma: among athletes aged 15-19 y: 29% of the skiers and 17% of the orienteers reported asthma (<i>P</i> = .071); among the athletes aged 20-34 y: 35% of the skiers and 16% of the orienteers (<i>P</i> = .029); among the former skiers aged 40-94 y: 22%
Pedersen ²² (2008)	Cross-sectional study with 2 visits n = 100 adolescents aged 12-16 y; n = 33 (15 females) adolescent elite swimmers; n = 35 (19 females) unselected adolescents; n = 32 (13 females) adolescents with asthma	Swimming	• AHR to methacholine challenge: 20% fall in FEV₁ at a cumulative dose of methacholine of either PD₂₀ ≤ 2 μmol or PD₂₀ ≤ 8 μmol • EVH test: fall in FEV₁ of at least 10% of the prechallenge value	Swimmers were more responsive to EVH (8.1; 1.1 to 48.2) than unselected subjects (3.6; -2.0 to 13.8, <i>P</i> < .01) but less responsive to methacholine compared with subjects with asthma (0.9; -0.1 to 28.2 vs 2.2; -0.3 to 190.1, <i>P</i> < .05)

(continued)

TABLE I. (Continued)

First author (year)	Study and participant characteristics	Sport	Asthma outcome	Main results
Rika ²³ (2008)	Cross-sectional study. Primary data collected at Ragunan Sport School Jakarta. July to August 2004 n = 168 athletes and 12 sport types (71 females); mean age: 15.87 ± 1.49 y	Archery, athletics, gymnastics, lawn tennis, swimming, table tennis, taekwondo, volleyball, weightlifting, badminton, basketball, soccer	EIB: decline in FEV₁ as much as 10% or more from baseline value	Positive EIB: 23 athletes (17 females); highest percentage of EIB: taekwondo (54.5%) 16 athletes with EIB (70%) were from less asthmogenic sports
Robinson ²⁴ (2019)	Individual cases Case 1: 18-y-old male junior national middle distance swimmer who reported shortness of breath, cough, and chest tightness in conjunction with maximal effort training sessions or competition Case 2: 15-y-old female group distance swimmer who reported symptoms of shortness of breathing and occasional wheezing in conjunction with maximal effort training sessions or competition Case 3: 14-y-old female group distance swimmer who reported symptoms of shortness of breath in conjunction with maximal effort training sessions or competition Case 4: 14-y-old female group sprint swimmer who reported symptoms of wheezing and chest tightness in conjunction with maximal effort training sessions and competition	Swimming	- Case 1: positive bronchodilation - Case 2: no diagnosed asthma; 24-y-old sister diagnosed with EIB - Case 3: no diagnosed asthma; EIB-based reported symptoms - Case 4: allergic response to grass and trees; asthma diagnosed; exercised-induced laryngeal obstruction Clinical management: Case 1: β ₂ -agonist Case 2: No Case 3: β ₂ -agonist Case 4: emergency inhaler-β ₂ -agonist	Case 1: lack of postexercise clinical symptoms; baseline FEV ₁ of 138% predicted; maximal FEV ₁ decline of 6% Case 2: lack of postexercise symptoms Baseline FEV ₁ was 125% of the predicted value with a 29% decline after the training session Case 3: lack of postexercise symptoms with an FEV ₁ of 109% predicted and a 7% decline after training Case 4: lack of postexercise symptoms with an FEV ₁ of 105% predicted and a 13% decline after training
Rupp ¹³ (1992)	Cross-sectional study; school setting from Richmond County, Ga (1989-1990) N = 1241 (63% males) middle and high school student athletes	Football, basketball, baseball, soccer, track/cross-country, tennis, golf, softball, cheerleading	Risk of EIB: history of exercise-related dyspnea, cough, wheezing, or chest tightness OR history of intermittent episodes of reactive airway disease for which the athlete was not receiving regular treatment OR baseline FVC or FEV ₁ of <80% OR FEV ₁ /FCV of <80% - EIB: absolute decrease in FEV₁ of ≥15% - Symptomatic EIB: absolute decrease in FEV₁ of >20% Clinical management: inhaled β ₂ -agonist	66 of 230 students who completed the exercise challenge: >15% reduction in FEV ₁ ; among these, 50 had >20% reduction (prevalence of undiagnosed EIB = 29%); prevalence of EIB among the students identified to be at risk on the basis of medical history only: 28% Prevalence of EIB among students with positive results of spirometry but no medical history: 15% Prevalence of EIB among students with medical histories and positive spirometry: 61%

Sidiropoulou ²⁵ (2012)	Cross-sectional; club settings relative to each sport and developmental medicine and special education facilities, northern Greece n = 90 male adolescents; 3 groups— football, basketball, and water polo—of 30; aged 14-18 y	Football, basketball, water polo	• EIA: FEV₁ fall ≥10% at least in 1 measurement • Reevaluation for those exhibiting a ≥10% drop in FEV₁	22 athletes (9, 8, and 5 from football, basketball, and water polo, respectively): FEV ₁ ≥ 10 drop Reevaluation: 9 athletes (5 of 9, 4 of 8, and 0 from football, basketball, and water polo: FEV ₁ ≥ 10 drop) Trend of lower incidence of EIA in water polo athletes
Sue-Chu ²⁶ (1996)	Cross-sectional study; Norway and Sweden n = 171 elite cross-country skiers in Trondelag, Norway (n = 118, 76% males, 17.0 ± 1.1 y) and Jämtland, Sweden (n = 53, 68% males, 18.4 ± 1.4 y) from senior secondary schools or military service skiers (only for Sweden)	Ski	• BHR to methacholine: PD₂₀ FEV₁ of ≤1800 µg methacholine • Positive asthma symptomatology: wheeze within the last year and abnormal breathlessness or chest tightness present within the last year either on exertion, at rest, or on exposure to irritants • Current asthma: presence of positive asthma symptomatology and BHR at the time of investigation Total asthma: current asthma in addition to physician-diagnosed asthma currently treated with steroids	Prevalence BHR significantly different between countries (14% Norway vs 43% Sweden athletes, <i>P</i> < .001); Prevalence of clinically diagnosed asthma: 12% and 42% for Norway and Sweden, respectively (<i>P</i> < .001) Self-reported frequency of respiratory allergy: 32% for Sweden and 11% for Norway
Sue-Chu ²⁷ (1999)	Cross-sectional; 2 study populations: BHR to (1) adenosine 5'-monophosphate (AMP); and to (2) nitric oxide Competitive cross-country skiers, patients with asthma, and healthy controls AMP study: 18 skiers (10 males, mean age: 18.5 y; 16-27 y) and 29 patients with asthma (nonsteroid: 5 males; mean age: 16-31 y and steroid: 2 males; mean age: 37.7 y; 18-61 y); exhaled NO study: 44 skiers (25 males; mean age: 17.4 y; 16-20 y), 29 patients with asthma (12 males; mean age: 16.5 y; 13-19 y) and 82 controls (37 males; mean age: 16.0 y; 13-19 y)	Ski	• Asthma symptoms in skiers: wheeze and abnormal breathlessness or chest tightness, which was present on exertion, exposure to irritants, or at rest • Asthma symptoms in patients with asthma: wheeze or abnormal breathlessness with or without exposure to pollen, household pets, or house dust • Asthma in skiers: presence of asthma symptoms and BHR to methacholine • BHR: cumulative dose that caused a decline in FEV₁ by 20% or more from baseline Clinical management: AMP study: ICSs	AMP study: -Prevalence of BHR was 28%, 40%, and 71% for patients with asthma, nonsteroid, and steroid groups, respectively. -AMP increased from patients with asthma, nonsteroid, and steroid-treated asthma (but no significant differences between them) Exhaled NO study: -No significant differences between ski asthma and healthy subjects -Exhaled NO in 29 subjects with mild intermittent asthma significantly higher than in skiers (median [interquartile range], 19.2 [5.1-25.6] ppb; <i>P</i> < .01) -Exhaled NO significantly higher in atopic compared with nonatopic in the skiers (<i>P</i> < .001) and patients with asthma (<i>P</i> < .001) -Exhaled NO correlated to methacholine responsiveness in atopic patients with asthma (<i>ρ</i> = 0.55; <i>P</i> < .01)

(continued)

TABLE I. (Continued)

First author (year)	Study and participant characteristics	Sport	Asthma outcome	Main results
Van der Eycken ²⁸ (2016)	Flemish future team n = 44 young athletes (n = 13 basketball, 7 males, mean age = 12.4 ± 0.49 y; n = 19 football, 15 males, mean age = 12.88 ± 0.67 y; n = 12 swimming, 10 males, mean age = 12.92 ± 0.76 y), aged 12–14 y and n = 8 age-matched controls, performing recreational level recruited from regular high schools (2 males, 13.79 ± 0.89 y)	Basketball, football, and swimming	EIB: fall in FEV ₁ ≥10% after eucapnic voluntary hyperventilation test	Prevalence of EIB: 23% for basketball, 21% for football, and 58% for swimming athletes; 13% for controls

FEF₂₅₋₇₅, Forced expiratory flow at 25% to 75% of forced vital capacity; FVC, forced vital capacity; ICS, inhaled corticosteroid; LABA, long-acting β₂-agonist; PEF, peak expiratory flow; PFT, pulmonary function test; RCT, randomized controlled trial.

vasoconstriction of peribronchial venules to conserve heat; when exercise ceases, a rebound vasodilatation occurs, with engorgement of the venous plexus, mucosal edema, and smooth muscle constriction.

These 2 mechanism may work together under condition of significant heat loss, causing inflammation and airway engorgement.¹⁵

Are some sports more “asthmogenic”?

EIB and asthma symptoms are frequently reported by adolescents undertaking endurance sports, with winter-sport athletes and swimmers being more likely to have these symptoms than those practicing summer-sports. The type of training and having atopy³¹ are 2 recognized independent risk factors for EIB: combining the 2 factors in a logistic regression model, atopic speed, and power athletes have a 25-fold increased risk of EIB compared with nonatopic subjects, long-distance runners a 42-fold, and swimmers a 92-fold increased risk.³¹ Adolescent cross-country skiers¹⁹ have been reported to have a higher prevalence of symptoms compared with, for example, those practicing sports that rarely require a continuous effort of more than 5 to 8 minutes such as tennis, sprint (track and field), fencing, or team sports in general²¹ (Table II).

Couto et al³² recently identified 2 asthma phenotypes in athletes: (1) atopic asthma, defined by the occurrence of atopy, increased levels of fractional exhaled nitric oxide, (allergic) rhinitis, and/or other allergic comorbidities, and (2) sport asthma, defined by the presence of exercise-induced respiratory symptoms and bronchial hyperresponsiveness (BHR), not associated with allergic features but related to particular environments such as aquatic and winter sports, which have respectively a 3-fold and 9-fold increased risk of this specific phenotype of asthma.

Asthma in the young top-level athletes: Role of the environment

Top-level athletes show a higher prevalence of EIB, and a peculiar pathophysiological mechanism involving airway epithelial damage and reduced repair seems to be central. One study has reported that up to 50% of young elite athletes could suffer from asthma.²⁸

Epithelial injury is the final result of inhalation of air pollutants and poorly conditioned air during repeated courses of high-intensity training and competitions.^{33,34} It is clear that the environmental conditions in which sports and training are practiced are important for the respiratory health of the adolescent athlete.³³ Different types of sports have different environmental exposures. For example, cross-country skiers are constantly exposed to cold and dry air, and athletes training and competing in ice rinks are likely to be exposed to NO_x from the freezing machinery, and to CO₂, NO₂, and ultrafine particles from the resurfacing machines.³⁵

The case of swimming and water sports

For years, swimming has been considered a safe and healthy sport for children and adolescents with asthma, due to the warm and humid air inhaled in the swimming pools. However, 25% to 50% of young competitive swimmers might suffer from EIB.^{22,28,36,37} This higher prevalence of EIB might be related to the presence of chlorination by-products from the pool water, which are likely to cause epithelial injury.³³

TABLE II. Sports and potential risk of EIB/EIBa

Low-risk sports	Medium-risk sports	High-risk sports
All sports in which the athlete performs a <5-8-min effort	Team sports in general, in which the continuous effort rarely lasts more than 5-8 min	All sports in which the athlete performs a >5-8-min effort and/or in a dry/cold air environment
Track and field:	Soccer	Track and field:
• Sprint (100, 200, 400 m)		• Long distance (5,000, 10,000 m)
• Middle distance (800, 1500 m)		• 3,000 m steeplechase
• Hurdles (100, 110, 400 m)		• Pentathlon (mixed)
• Jumps		• Walks (20 and 50 km)
• Throws		• Marathon
• Decathlon		• Scuba diving
• Eptathlon		• High-altitude sports
Tennis	Rugby	Cycling
Fencing	American football	Cross-country skiing
Gymnastics	Basketball	Ice hockey
Downhill skiing	Volleyball	Ice skating
Boxing	Handball	Biathlon
Golf	Baseball	
Body-building	Cricket	
Weightlifting	Field hockey	
Martial arts		
	Swimming, water polo	

Adapted with permission from Del Giacco et al.¹¹

Despite the relatively similar environmental exposures, the participation in competitive swimming activities is associated with a higher prevalence of asthma/BHR, when compared with 5 other aquatic disciplines.³⁸ Young competitive swimmers develop BHR earlier than other athletes.^{33,39,40} They do not have significant signs of airway damage in their earlier years of intense training and competition, which suggests that elite swimmers do not have particularly susceptible airways when they take up competitive swimming when young, but they develop respiratory symptoms, airway inflammation, and BHR during their swimming careers.²² In the setting of competitive swimming, air quality can be influenced not only by chlorine derivatives but also by ozone and combustion-derived pollutants, such as oxides of nitrogen, as well as particulate matter.⁴¹ These, and other air pollutants including sulfur dioxide and carbon oxides, are constantly released into the atmosphere and affect the health condition, especially of individuals with asthma. This effect on athletes is more pronounced because metabolic demands of exercise increase minute ventilation and therefore the rate of inhalation of pollutants increases.⁴²

In the case of swimmers, many athletes with EIB also may finally develop EIBa, because of the repeated courses of intensive training sessions and competitions that reduce the repair of the respiratory epithelial damage.¹⁵ This mechanism seems to be transitory and is at least partially reversible at the end of career.⁴³⁻⁴⁵

The adolescent athlete with asthma: The “A” triad of difficulties

Asthma can become a major concern during adolescence. Managing a chronic illness during adolescence can conflict with the physical, cognitive, emotional, and psychological changes associated with puberty and normal development.⁴⁶ The

influence these changes exert on pathophysiology, presentation, prognosis, and treatment of asthma must be carefully considered. For example, poor adherence to treatment is very common during adolescence. During this time, there is an increasing sense of independence, wanting to test limits and boundaries, and not wanting to be “told” what to do, including taking medications.⁴⁷

Most young people with asthma have a healthy self-image.⁴⁸ However, adolescents with asthma are more likely to resent the condition and feel different to their peers, leading to them resenting or ignoring the disease. At the same time, adolescents with asthma take on the same risky activities as their peers, such as smoking.⁴⁹ Adolescence is a period of particular vulnerability because adolescents are taking increasing control of their asthma management although they often underestimate the severity of their disease and overestimate its control.⁵⁰ Smoking and psychosocial factors⁵¹ (eg, anxiety, depression, risky behaviors, and family dysfunction) can also be associated with deteriorating asthma control.

Asthma can also have an impact on social and academic life, often resulting in isolation. Feelings of ostracism are often cited by those with asthma, with some deliberately denying symptoms and “struggling through” exercises with their healthy peers to avoid social isolation⁵² and being identified as different.⁵³ Sometimes, adolescents consider their symptoms as a “normal” response to exercise, or prefer to hide them, possibly in fear of being dropped from their team.⁵⁴ Minimal difference in the perception of bronchoconstriction-related symptoms was recently observed between athletes and non-athletes (aged 14-35 years), but worse perception was noticed in the younger.⁵⁵ Thus, relying on symptoms to diagnose asthma in adolescent athletes will most likely lead to underdiagnosis of this condition.

TABLE III. BPTs and positivity criteria used to identify BHR for the correct diagnosis of EIB

Method	Positivity criteria
Direct BPTs	
- Methacholine challenge	PC ₂₀ ≤ 4 mg/mL or PD ₂₀ ≤ 400 µg (cumulative dose), or ≤ 200 µg (noncumulative dose) in those not taking ICS PC ₂₀ ≤ 16 mg/mL or PD ₂₀ ≤ 1600 µg (cumulative dose) or ≤ 800 µg (noncumulative dose) in those taking ICS for at least 1 mo
- Histamine challenge	≥20% decrease in FEV ₁ at a histamine concentration of 8 mg/mL or less during a graded test of 2 min
Indirect BPTs	
- Exercise challenge (field or laboratory)	≥10% decrease in FEV ₁ from baseline
- EVH	≥10% decrease in FEV ₁ from baseline
- Hypertonic saline inhalation	≥15% decrease in FEV ₁ from baseline
- Mannitol inhalation	PD _{15M} ≤ 635 mg of mannitol

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BPT, Bronchial provocation test; ICS, inhaled corticosteroid; PC₂₀, provocative concentration of methacholine that causes a 20% drop in FEV₁; PD₂₀, provocation dose causing a 20% decline in FEV₁.

Adapted from Couto et al.⁶⁴

The impact of EIB

Asthma-like symptoms in the young athlete not only have a pathophysiological impact but can also impair their psychological and emotional well-being.⁵⁶ In the United States, adolescent athletes who reported dyspnea during exercise showed significantly lower scores for health-related quality of life (QOL), including subscores for physical and emotional functioning and general well-being, compared with those without exercise-associated dyspnea.⁵⁷ Similar findings were reported in a Swedish study of adolescents that reported an association between exercise-induced symptoms and reduced health-related QOL.⁵⁸ Girls with EIB also exhibited significantly higher scores for anxiety, but not depression, compared with girls without EIB.⁵⁸

Because anxiety and depression are not uncommon in adolescents with asthma, the inclusion of psychological support as part of the asthma treatment has been shown to improve the overall management of the condition.⁵⁹ However, it is likely that the levels of anxiety vary depending on the type of sports practiced, which highlights the need to generate more evidence on the psychological impact of asthma-like symptoms.⁶⁰

DIAGNOSIS

Diagnosis of EIB/EIBa is usually made in secondary care settings. Resting spirometry measurements are poor predictors of variable airflow obstruction in athletes,⁶¹ as seen in several athletes whose lung function at rest is often above predicted values.⁶² The use of respiratory symptoms alone is strongly discouraged for diagnostic purposes,⁶³ because symptoms are neither sufficient nor essential to confirm the presence of EIB/EIBa in young athletes.^{22,28,36,37} However, symptoms are fundamental to refer the athlete for a check, even if a significant number of young asymptomatic athletes with no previous history or diagnosis of asthma actually may have EIB.^{22,28,36}

Spirometry with bronchodilator reversibility testing can be considered as the first-line test for athletes with asthma with symptom triggered by exercise (EIBa), but not for the one with EIB only. Easy to perform, it tests positive when FEV₁ bronchodilator reversibility is greater than or equal to 12% or 200 mL.

Bronchial provocation tests are used to identify BHR and to aid the diagnosis of EIB in athletes,⁴¹ and are mandatory for athletes using antiasthmatic drugs and subject to antidoping

scrutiny following the World Anti-Doping Agency recommendations. There are various available bronchial provocation tests, both indirect and direct, in which the diagnosis of EIB should be based (Table III), all being mostly safe, well accepted, and relatively inexpensive.⁵⁴ However, the airway response to bronchial challenge may vary with several factors, including the age of the athlete; it is also important to consider the stimulus used, the sport the athlete competes in, and the time of the year/sporting season when the test is conducted.⁵⁴

Testing directly for bronchial responsiveness using bronchial challenge with methacholine has a higher sensitivity, but a lower specificity, for asthma.^{35,40,65}

With a high specificity, field exercise is an obvious first and recommended choice for investigation of young athletes with suspected EIB.⁶⁶ However, if poorly standardized (eg, if humidity of the inhaled air is not controlled), its sensitivity can be significantly reduced, and logistical issues make this test difficult to perform in reality.

Despite not many facilities being equipped to perform eucapnic voluntary hyperpnea (EVH), this test is a highly standardized and sensitive tool, widely recommended for EIB detection in adult athletes.⁶⁷ However, when done in young athletes, the target ventilation of 85% of maximum voluntary ventilation may need adjustment.²⁸ Because of its high potency, EVH is not recommended in athletes with a history of severe clinical asthma; for these, the progressive osmotic challenge tests (ie, 4.5% saline or powder mannitol) should be preferred.⁵⁴ In particular, mannitol test can be easily performed without any special equipment except a spirometer.

Some athletes may continue to present with EIB symptoms although they test negative during an adequate exercise challenge test or EVH. As a result, it has been suggested that a second challenge is necessary to improve the sensitivity of the challenge test.¹⁵

A brief flowchart for diagnosis can be found in Figure 1.

The problem of underdiagnosis

There is growing evidence that objectively confirmed EIB/EIBa is more prevalent than would be assumed from using self-reported symptoms alone,^{68,69} possibly because a decline in lung function postexercise (the criterion for EIB) may occur in the

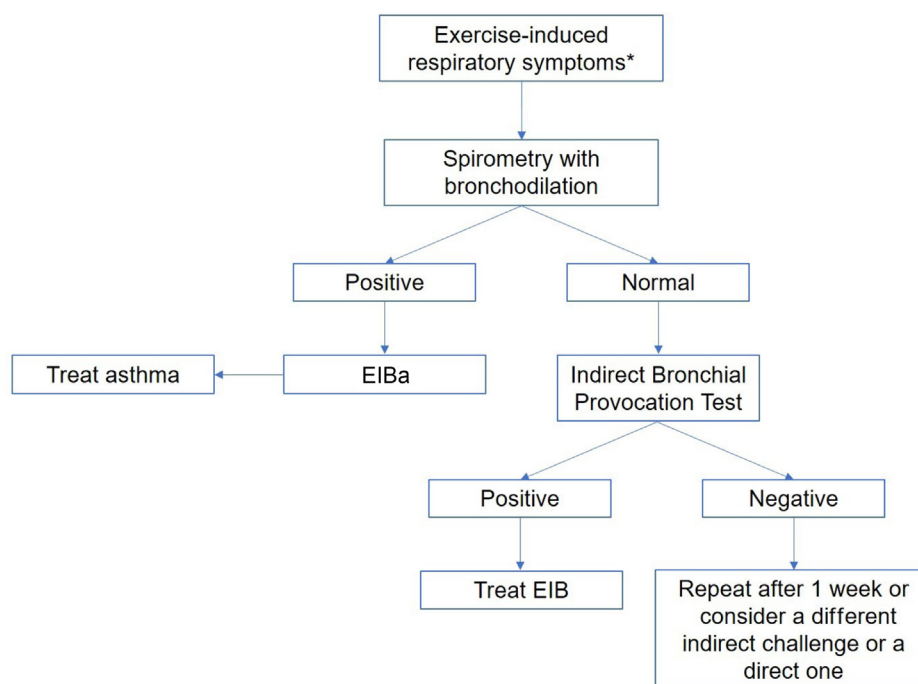


FIGURE 1. Proposed diagnostic flowchart when EIB is suspected in young athletes. *In a healthy adolescent with without a prior history of asthma.

absence of symptoms,⁶² and also because symptoms are often ignored by adolescents.

College athletes' perceived symptoms have not been associated with their results when performing a standardized EIB test.⁷⁰ They may discount exercise-induced symptoms as due to bad conditioning or a poor training day. Furthermore, EIB/EIBa is frequently underdiagnosed because of lack of awareness among athletes and athletic trainers.^{71,72} This lack of awareness and subsequent misperception of symptoms may lead to unnecessary morbidity and potential mortality in college athletes. Previous studies on college athletes indicated that self-reporting positive symptoms and history of asthma were not associated with a positive EVH test result.^{68,73}

Hammerman et al¹⁷ used a free running test (Free-Running Asthma Screening Test) to screen high school athletes. Although 46 of the 801 athletes were known to have asthma before the screening, 39 (85%) still developed EIB despite using their medications, suggesting undertreatment. Free-Running Asthma Screening Test can be an acceptable, feasible, and cost-effective mass screening test⁷⁴ also in primary care, even if not in line with the current guidelines.

Finally, the impact of rhinitis on asthma must also be considered.⁷⁵ Asthma and rhinitis frequently coexist, even in the absence of atopy.⁷⁶ About 80% to 90% of patients with asthma report rhinitis symptoms and 19% to 38% of patients with allergic rhinitis report symptoms of asthma. Rhinitis is frequent in athletes,⁷⁷ with a variable prevalence depending on the criteria used for diagnosis in different studies.

Differential diagnosis

Other clinical entities can mimic asthma and might lead to an incorrect diagnosis (Table IV).⁶⁴ Exercise-induced dyspnea can

be caused by various etiologies, sometimes concomitant. A differential diagnosis should be taken into consideration when an athlete continues to present with symptoms of EIB after testing negative. The most common diagnostic entities with symptoms that may mimic EIBa include vocal cord dysfunction (exercise-induced laryngeal obstruction), overtraining syndrome, right to left cardiac shunt, physical deconditioning, and even hyperventilation syndrome, each with distinctive characteristics.^{64,78}

TREATMENT

Pharmacological treatment

Several guidelines and recommendations on EIA, EIB, and EIBa have been published during the last 15 years. Between them, after the European Academy of Allergy and Clinical Immunology/European Respiratory Society joint documents in 2008,^{10,79} the first practice parameter on EIB was published in 2010,⁸⁰ later updated in 2016.⁹ Meanwhile, an Official American Thoracic Society Clinical Practice Guideline on Exercise-induced Bronchoconstriction was published in 2013.⁶⁶ Also of notice, yearly Global INitiative for Asthma guidelines addressed the issues of EIB in the context of asthma, the latest dated of 2020.⁸¹ The differences between these more recent documents (Table V) are not only about new evidence arising from more recent studies but also about whether EIB alone or EIBa is being considered.

EIBa and EIB are usually treated with the same drugs, using a slightly different approach for each condition. In patients with EIBa, the occurrence of exercise-induced symptoms should be regarded as a sign of poor asthma control. Those athletes who achieve good overall asthma control but retain EIBa will first require a step-up in their controller treatment following global treatment guidelines. This will ensure that the underlying asthma

TABLE IV. EIB/EIBa: Differential diagnosis

Diagnosis	Relevant for	Clinical presentation	Verification of diagnosis
EIB/EIBa		Symptoms occur shortly after (sometimes during) physical exercise. The dyspnea is of expiratory type. By auscultation: Rhonchi and sibilating rhonchi. Respiratory retractions. Gradual improvement either spontaneously or after inhaled bronchodilator	Exercise test with submaximal exercise load (95% load) Spirometry before and after exercise
Exercise-induced vocal cord dysfunction	Patients with asthma and individuals active in sports	Symptoms occur during maximum exertion. Symptoms disappear when exercise is stopped unless the patient continues to hyperventilate. The dyspnea is of inspiratory type. There are audible inspiratory sounds from the laryngeal area and no signs of bronchial obstruction. No effect of pretreatment with inhaled bronchodilator	Exercise test with maximal exercise load, 6-8-min duration Direct laryngoscopy during exercise test
Exercise-induced hyperventilation	Individuals active in sports, general population	Hyperventilation with respiratory dyspnea and increased end-tidal CO ₂	Case history, observation during dyspnea
Exercise-induced arterial hypoxemia	Individuals active in sports	Occurs in well-trained athletes with high maximum oxygen uptake. Thought to be due to diffusion limitations and ventilation-perfusion inequality. Incomplete diffusion in the healthy lung may be due to a rapid red blood cell transit time through the pulmonary capillaries	Exercise test, submaximal to maximal level
Swimming- induced pulmonary edema	Individuals active in sports	May occur after heavy swimming exercises with symptoms of hemoptysis, cough, and respiratory distress. Reduced diffusion capacity (TLCO) for up to weeks afterwards	Case history, clinical examination, and lung function measurements during an active episode
Other chronic lung diseases	Individuals with chronic lung disease	Reduced baseline lung function may reduce physical performance due to limitations in airflow and lung volumes	Exercise test with measurement of tidal flow volume loops during exercise
Other general disease	Individuals with chronic illnesses —cardiovascular disorders	Chronic heart diseases and others general disorders	General diagnostic workout
Poor physical fitness including obesity	General population	Related to expectations. High heart rate after low- grade exercise load	Exercise test: Assessment of physical fitness by determination of VO ₂ max or maximal exercise load

Modified from Del Giacco et al.¹¹ with permission.

TLCO, Transfer capacity of the lung, for the uptake of carbon monoxide.

TABLE V. Comparison between different guidelines on treatment of EIB

EIB		EIBa or EIA
ATS ⁶⁶ (2013)	Practice parameter update ⁹ (2016)	GINA ⁸¹ (2020)
For patients with EIB, we recommend administration of an inhaled SABA before exercise (strong recommendation, high-quality evidence), typically 15 min before exercise.	Prescribe inhaled SABAs for protection against EIB and for accelerating recovery of pulmonary function when given after a decrease in pulmonary function after exercise (Strength of Recommendation: Strong; Evidence: A).	Taking SABAs, LABAs, or cromones before exercise prevents EIB (Evidence A), but tolerance to the protective effects of SABAs and LABAs against EIB develops with regular (more than once daily) use (Evidence A).
A controller agent is generally added whenever SABA therapy is used daily or more frequently or for patients with EIB who continue to have symptoms despite using an inhaled SABA before exercise.	Prescribe a single dose of SABA, LABA, or both on an intermittent basis (ie, <4 times per week) before exercise (Strength of Recommendation: Strong; Evidence: A).	Preferred Step 1 controller (adults and adolescents <i>with asthma</i>): low-dose combination ICS-formoterol taken as needed for relief of symptoms and if needed before exercise. For preexercise use in patients with mild asthma, low-dose budesonide-formoterol for symptom relief and before exercise reduced EIB to a similar extent as regular daily low dose of ICS with SABA for symptom relief and before exercise (Evidence B).
We recommend against daily use of a LABA as single therapy (strong recommendation, moderate-quality evidence).	Be cautious in daily use of β_2 -adrenergic agents alone or in combination with ICSs because this can lead to tolerance (Strength of Recommendation: Strong; Evidence: A).	Preferred Step 2 controller (adults, adolescents, and children <i>with asthma</i>): regularly daily low-dose ICS plus as-needed SABA and preexercise (Evidence A).
We recommend daily administration of ICS (strong recommendation, moderate-quality evidence).	Consider prescribing daily therapy with LTRAs because this does not lead to tolerance and has been shown to attenuate EIB in 50% of patients. It can also be used for intermittent or maintenance prophylaxis; however, it provides incomplete protection and is not effective for reversing airway obstruction (Strength of Recommendation: Strong; Evidence: A).	Other Step 2 controller options for adults and adolescents <i>with asthma</i> : LTRAs are less effective than ICSs, but may be appropriate in some patients who are unable or unwilling to use ICSs, with side effects of ICSs, or with concomitant allergic rhinitis
We recommend against administration of ICS only before exercise (strong recommendation, moderate-quality evidence).	Consider prescribing inhaled cromolyn sodium and nedocromil sodium (currently not available in the United States as a metered-dose inhaler or dry powder inhaler) shortly before exercise; this attenuates EIB but can have a short duration of action. There is no bronchodilator activity. They might be effective alone or as added therapy with other drugs for EIB (Strength of Recommendation: Strong; Evidence: A).	
We recommend daily administration of an LTRA (strong recommendation, moderate-quality evidence).	Consider prescribing ICSs in combination with other therapies because ICSs can decrease the frequency and severity of EIB but not necessarily eliminate it (Strength of Recommendation: Strong; Evidence: A).	
We recommend administration of a mast cell – stabilizing agent before exercise (strong recommendation, high-quality evidence).	Do not prescribe daily LABAs with ICS therapy to treat EIB unless needed to treat moderate to severe persistent asthma. The ICSs might not prevent the occurrence of tolerance from daily β_2 -agonist use (Strength of Recommendation: Strong; Evidence: A).	
We suggest administration of an inhaled anticholinergic agent before exercise (weak recommendation, low-quality evidence).	Consider prescribing inhaled ipratropium bromide for patients who have not responded to other agents; however, its ability to attenuate EIB is inconsistent (Strength of Recommendation: Weak; Evidence: A).	

ATS, American Thoracic Society; GINA, Global INitiative for Asthma; ICS, inhaled corticosteroid; LABA, long-acting β_2 -agonist; LTRA, leukotriene receptor antagonist.

is under control and the reduction in risk (or prevention entirely) of the occurrence of EIBa is achieved, allowing the patient to continue engaging in sports with minimal respiratory symptoms.

For young and adolescent athletes with EIB (ie, athletes who have no symptoms except during exercise), and when only intermittent symptoms are present, guidelines recommend as-needed preventative and reliever medication, again with short-acting beta-2 agonists (SABAs) 15 to 20 minutes before exercise and as a reliever if needed.^{9,80}

However, some important considerations are necessary regarding the use in monotherapy of β_2 -agonists in EIB/EIBa. First, because of the high heterogeneity in the airway response to β_2 -agonists,⁸² not all individuals may gain bronchoprotection from this class of drugs⁵⁴ and in 15% to 20% of patients SABAs seem to not offer protection against EIB.^{82,83} Furthermore, frequent use in monotherapy of β_2 -agonists, both SABAs and long-acting β_2 -agonists, can be associated with tachyphylaxis,⁸⁴⁻⁸⁶ also when treating bronchoconstriction in subjects with exercise-induced symptoms, with loss of efficacy from this class of drugs. In addition, it has been suggested that airway inflammation could potentiate downregulation of bronchoprotection in response to β_2 -agonists,⁸⁷ reinforcing the concept that long-acting β_2 -agonists should never be used regularly without an inhaled steroid.⁸¹

Consequently, in athletes with EIB and frequent symptoms or in top athletes, a treatment primarily based on daily inhaled corticosteroids is recommended, with SABAs as a preventative and reliever medication and long-acting β_2 -agonists used in combination with inhaled corticosteroids as a controller treatment for more severe cases.⁷⁹ Another option as an add-on treatment to inhaled corticosteroids is leukotriene receptor antagonists, for which, unlike the β_2 -agonists, on the one side tachyphylaxis has never been reported, but on the other side only a few studies have been performed to assess the effect of montelukast and they have presented some divergent results.⁶⁴

However, although studies in young athletes show that use of β_2 -agonists is the treatment of preference to minimize or prevent symptoms of EIB, one should be aware that patients with asthma may not adhere to their prescribed medication treatment^{88,89} and when pharmacologic treatment is necessary, the National Athletic Trainers Association guidelines suggest that athletic trainers in direct contact with athletes should understand the use, misuse, and abuse of β_2 -agonists.⁷¹

Even though ergogenic effects of inhaled β_2 -agonists in those without asthma have been disproven,⁷⁹ elite athletes with EIB are still subjected to scrutiny, which can lead to negative stigma.⁹⁰ Only about 20% of individuals experiencing exercise-related symptoms reported taking quick-relief medications before exercise “always” or “most of the time.”^{70,91}

In athletes with concomitant allergic rhinitis, appropriate treatment must be provided, and allergen immunotherapy can be considered in selected cases.⁷⁷

Current antidoping regulations from the World Anti-Doping Agency or other national and international bodies must be always considered when prescribing an antiasthmatic or anti-allergic drug to a competitive adolescent or high school athlete (see reference⁹²).

Nonpharmacological interventions

There are various nonpharmacological approaches recommended to reduce the risk of bronchoconstriction in athletes

with asthma, which include nasal breathing; interventions that prewarm and humidify inhaled air during exercise (eg, breathing through a face mask or scarf); treatment of associated comorbid conditions; and environmental control.

Environmental control is an important part of caring for these athletes,³³ with measures including (1) optimal ventilation of swimming pools to reduce the amount of inhaled chlorine products; (2) environmental control of indoor skating arenas and sports arenas; (3) giving preference to pollution-free outdoor locations for sport events; (4) suspending winter endurance competitions if outside temperatures fall below -15°C ; and (5) avoiding/reducing exposure to environmental allergens in the athletes who are allergic.⁹³

Warm-up before exercise is pointed out as one of the most relevant effective measures at avoiding bronchoconstriction. High-intensity, intermittent (15-30-second exertions alternate with 60-90-second rest), varied exercise of 10 to 15 minutes or moderately vigorous exercise before the planned period of exercise or competition followed by a warm-down segment induce the refractory period, during which EIB symptoms may be reduced.^{15,33}

Breaking down barriers and increasing support

A common challenge for adolescent athletes with asthma is adherence to the medication and treatment.^{70,90} This may be related to a number of issues, including (1) the lack of awareness about EIB among sports teams and personnel; (2) education of the athletes and parents; (3) experiencing adverse reactions; and (4) feeling an absence of benefit from asthma medication. Adolescents with poor knowledge of asthma, their medications, or their appropriate use are less likely to be adherent to their treatment.⁹⁴ Adolescents who reported a greater knowledge of asthma reported far fewer barriers to self-management.⁹⁴ Education (including up-to-date information on antidoping regulations) should therefore be at the cornerstone of asthma management in all athletes.⁹⁵ The burden of EIB in college athletes may be improved by (1) educating athletes, trainers, coaches, and parents about EIB; (2) helping in the development of accurate EIB screening programs; and (3) ensuring the proper treatment of EIB-positive athletes to mitigate associated morbidity and mortality.⁷⁰ Athletes may attribute EIB symptoms to a cause other than respiratory issues. Specialists in respiratory care need to do a better job at teaching awareness of EIB/EIBa to athletes, coaches, trainers, and parents.⁷⁰

To this end, a number of studies have explored how to equip trainers and coaches with tools to support adolescent athletes. The National Athletic Trainers Association's statement provides a structured framework to improve the asthma management in young athletes.⁷¹ Importantly, educating and informing the trainer can greatly help identify those athletes presenting difficulties with their asthma, and to prepare a management plan.⁷¹ It has been demonstrated that having a management plan in place helps both the athlete and the trainer to deal with the adherence to treatment (when required) and to identify potential medication errors, or need for additional medical support (eg, hospital visits).^{6,71} Lack of such a structured plan can lead to poorer adherence to treatment and management.⁹⁶

Athletic trainers are in a unique position to recognize breathing difficulties caused by undiagnosed or uncontrolled asthma, particularly when asthma follows exercise. Once the diagnosis of asthma is made, the athletic trainer should play a

pivotal role in supervising therapies to prevent and control asthma symptoms.⁹⁷ With proper asthma education and training, athletic trainers can teach athletes with known asthma or EIB how to promptly identify symptoms, and maximize the effectiveness of their prescribed medications and non-pharmacologic treatment strategies.⁹⁷ Ensuring environment and health coach education emphasizes athlete performance, whereas reducing risk is critical to promoting module application and providing safe and enjoyable youth team sport spaces.⁹⁸ Improving coach understanding and management of environment and health issues, specifically related to asthma management, will help reduce athlete vulnerability, provide safe and enjoyable youth team sport spaces, and increase sport participation and performance.⁹⁸

Social support from adolescents' friends has been identified as one of the strongest predictors of good asthma control.⁹⁹ High levels of support can change negative perceptions that adolescents may have toward asthma and promote positive attitudes toward self-care, enhancing treatment adherence. Sometimes, there are basic misunderstandings that can prevent effective treatment such as fears around side effects or long-term health effects, which, when addressed, greatly improve adherence to treatment.⁴⁶

One key aspect in the successful treatment of an elite athlete with asthma may be the role of shared decision making between the athlete and the health care provider and/or the provider's team.⁹⁰ Negotiating treatment plans may also be a key point during adolescence, but requires not only education but also exploring health beliefs, which can be significant, particularly from a cultural perspective.⁵⁶ Through shared decision making, a personalized asthma action plan is implemented that encompasses a self-management plan that is tailored to the athlete. This provides the athlete with individualized instructions for self-management of asthma or the control of an asthma exacerbation.⁹⁰

Physical activity as a way to improve exercise-induced symptoms

The recommendation of practicing regular sports to alleviate exercise-induced symptoms might appear as a contradiction. Experimental evidence suggests that regular low to moderate intensity aerobic exercise reduces eosinophilic and lymphocytic inflammation.¹⁰⁰ Other mechanisms through which exercise might protect against respiratory injury include reduction of airway smooth muscle hypertrophy and hyperplasia, leukocyte infiltration, and proinflammatory cytokine production.^{15,101}

In support of these findings, several studies have shown that children and adolescents with asthma who participate in regular physical training improve their aerobic fitness, QOL, and exercise level.^{35,102} The most consistent benefit of regular exercise is seen in the fewer number of hospital admissions, wheeze, use of medication, and school/college absenteeism.^{15,103,104} These benefits suggest that engaging adolescents in regular sports practice might contribute to improving asthma management and general well-being,¹⁵ while also reducing the side effects of a sedentary lifestyle.¹⁰⁴

Given the well-known health benefits of exercise in both the general population and individuals with asthma,⁸¹ the need to manage EIBa and EIB effectively is clear. An analysis of the impact of an aerobic training program on asthma-specific health-related QOL, asthma symptoms, anxiety, and depression scores

in patients with moderate or severe persistent asthma found that aerobic training had an important role in the clinical management of persistent asthma.¹⁰² Significant reductions in physical limitation and symptom frequency were reported in the training group compared with the control group. Moreover, only patients from the training group reported reductions in anxiety and depression levels.¹⁰²

Managing health risks in sport, considering the risk profiles of different stakeholders (eg, coaches, parents of vulnerable athletes), as well as the characteristics of the places in which risk is experienced, is critical to improving environment and health management in organized youth team sports.¹⁰⁵

CONCLUSIONS

It is reassuring that many athletes with asthma with optimal treatment participate at the same level as their peers in top-level competitions.¹⁵ Fitch¹⁰⁶ described that athletes with asthma even succeeded in winning more medals than other athletes in the Olympic Games.¹⁵ However, in high school and adolescent athletes, asthma-related symptoms are common, yet their presence involves a number of complex issues related to the diagnosis of asthma, its clinical management, the adherence to treatment, and the impact they have on QOL.

Some athletes may not be appropriately screened and may potentially be experiencing silent episodes of EIB, resulting in possible long-term respiratory health complications. Many athletes may fail to report symptoms suggestive of EIB and do not seek medical care to undergo a formal diagnosis. This may be attributed to athletes' lack of awareness of symptoms and their association with EIB. Rather than recognizing the potential of having EIB, athletes may consider their symptoms to be indicative of poor conditioning or a bad training day.

There is a need for better provision of respiratory care in young athletes; that service should come in the form of improved detection and better management.⁵⁴ Thus, moving away from symptom-based diagnosis of EIB/EIBa and incorporating objective testing via indirect bronchial provocation, with exercise or its surrogates, are warranted. To ensure the success of new initiatives, the changes should be driven by policies. Guidelines and policies should be supported by educational programs devised both for young athletes and for their support staffs (including coaches, team doctors, physiotherapists, etc). It is only when all stakeholders fully appraise the nature and extent of the problem that young athletes will finally get the level of respiratory care they deserve.

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