



Asthma prevalence in German Olympic athletes: A comparison of winter and summer sport disciplines[☆]



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ABSTRACT

Background: Prevalence of asthma in elite athletes shows very wide ranges. It remains unclear to what extent this is influenced by the competition season (winter vs. summer) or the ventilation rate achieved during competition. The aim of this study was to evaluate prevalence of asthma in German elite winter and summer athletes from a wide range of sport disciplines and to identify high risk groups.

Methods: In total, 265 German elite winter athletes (response 77%) and 283 German elite summer athletes (response 64%) answered validated respiratory questionnaires. Using logistic regression, the asthma risks associated with competition season and ventilation rate during competition, respectively, were investigated. A subset of winter athletes was also examined for their FE_{NO}-levels and lung function. **Results:** With respect to all asthma outcomes, no association was found with the competition season. Regarding the ventilation rate, athletes in high ventilation sports were at increased risk of asthma, as compared to athletes in low ventilation sports (doctors' diagnosed asthma: OR 2.32, 95% CI 1.19–4.53; use of asthma medication: OR 4.46, 95% CI 1.52–13.10; current wheeze or use of asthma medication: OR 2.78, 95% CI 1.34–5.76). Athletes with doctors' diagnosed asthma were at an approximate four-fold risk of elevated FE_{NO}-values.

Conclusions: The clinically relevant finding of this study is that athletes' asthma seems to be more common in sports with high ventilation during competition, whereas the summer or winter season had no impact on the frequency of the disease. Among winter athletes, elevated FE_{NO} suggested suboptimal control of asthma.

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1. Introduction

Asthma seems to be frequent in elite athletes and the prevalence has increased over the past few decades [1–3]. The prevalence of asthma in this group seems to be even higher than in the general

population [4–7]. However, depending on the study prevalence ranges between 2 and 52% [8–11]. Some studies suggest a higher prevalence of asthma in athletes competing in winter sports than in athletes competing in summer sports [12,13]. However, to date there has been only one other study published that compares the prevalence of asthma in elite winter and summer athletes from a wide range of sport disciplines. In this study, US athletes who participated in the 1998 Olympic Winter Games suffered more often from asthma than US athletes who participated in the 1996 Olympic Summer Games [14,15]. The prevalence of asthma in elite athletes varies widely between different sport disciplines [16,17]. It appears to be especially high among swimmers and athletes who take part in endurance sports [1,18–20]. Current studies explain this observation with different sport-specific environmental conditions and different ventilation rates achieved during competition associated with the sport discipline [1,4,5,21].

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Table 1
Classification of sport disciplines (modified from [32]).

Competition season	Ventilation rate achieved during competition		
	Low	Intermediate	High
Winter	bobsled, luge, skeleton, curling, ski jumping	alpine skiing, freestyle skiing, snowboarding, figure skating	biathlon, cross country skiing, nordic combined, ice hockey, speed skating, short track
Summer	archery, equestrian, fencing, gymnastics, judo, modern pentathlon, sailing, shooting, taekwondo, weightlifting	table tennis, volleyball, wrestling	athletics, badminton, basketball, canoe/kayaking, cycling, football, handball, hockey, rowing, swimming

Questions and definitions used in our study are shown in Table 2.

Among elite athletes, asthma is a significant problem. Asthma not only represents a health risk but also may interfere with the athletes' performance status [22,23]. If affected by asthma, athletes therefore need a reliable diagnosis and optimal treatment [1,24,25].

The objective of this study was to further evaluate prevalence of asthma in elite athletes and to identify high risk groups of athletes.

2. Methods

2.1. Study design and study participants

Within the framework of the Global Asthma and Allergy European Network (GA²LEN) [26], a cross-sectional, self-administered questionnaire survey of German elite winter athletes was carried out. The study protocol was approved by the Ethics Committee of the Medical Faculty of the Ludwig-Maximilians-University Munich. All potential candidates for the Olympic Games in Vancouver were invited to take part in the study. Only athletes over 18 years of age were included. All eligible athletes received a letter explaining the study, a consent form and the questionnaire. Athletes signed the consent form and completed the questionnaire. These data were compared with data obtained from German athletes participating in the Olympic Summer Games in Beijing, China 2008 [20,27]. These athletes had answered the same written questionnaire instrument prior to their participation in the Olympic Summer Games 2008. A total of 548 German elite athletes composed of 265 winter athletes (response 77%) and 283 summer athletes (response 64%) were examined in this study. In a subgroup of winter athletes FE_{NO}-levels and lung function was additionally assessed (N = 174, response 96%).

2.2. Questionnaire

All athletes were asked to complete the Allergy Questionnaire for Athletes (AQUA[®]) [28] and the European Community Respiratory Health Survey (ECRHS) screening questionnaire [29]. Both questionnaires were validated [28–31]. The aim of our analyses was to assess asthma in athletes. We therefore focused on the validated ECRHS questions for outcome assessment.

In order to assess training intensity, athletes were asked about their number of training sessions per week, accumulated duration of the weekly training sessions, location of training (mainly indoor vs. outdoor), and if they had competed earlier in another sport discipline. Sport disciplines were classified in three groups (Table 1): 1) Low ventilation sports, 2) intermediate ventilation sports, and 3) high ventilation sports, applying a sports classification published previously [32]. Ventilation needs were based on characteristics of the sport during competition. In this way, 143 athletes were classified as participating in low, 53 athletes in intermediate and 352 athletes in high ventilation sports.

The potential confounders age, sex, level of education, smoking, and frequency of exercise were considered. Athletes were classified as either smoker (current smoker and ex-smoker) or non-smoker

(never-smoker). Level of education was divided into less than 12 years of education versus 12 or more years of education.

2.3. Clinical measurements

The clinical measurements consisted of exhaled nitric oxide (FE_{NO}) measurements, followed by spirometry. Asthmatic athletes continued to take their asthma medication during the clinical measurements. It had been shown in previous studies that different factors might influence the result of the FE_{NO}-measurement [33]. Therefore, athletes who had exercised within the last 2 h (12 athletes), smoked during the last four weeks (2 athletes), had a respiratory infection during the last four weeks (5 athletes), or spirometry performed prior to the FE_{NO}-measurements (2 athletes) were excluded from the FE_{NO}-measurements.

FE_{NO}-measurements were performed with a portable measurement device (NIOX MINO[®], Aerocrine, Bad Homburg, Germany) according to international guidelines [34]. Afterwards, pulmonary function testing was performed using a bodyplethysmograph (ZAN 500 Plethysmograph, nSpire Health GmbH, Oberthulba), following the established guidelines [35]. At least three technically acceptable flow-volume manoeuvres were performed and the highest values were recorded. Predicted values were based on the reference values of the European Respiratory Society [36].

2.4. Statistical analysis

Statistical analyses were performed using SAS (Statistical Analysis System, version 9.1, SAS Institute Inc. Cary, NC, USA). For categorical data absolute (n) and relative (%) frequencies were determined and compared using the Chi-squared test. Results for continuous data were presented as mean (m) and standard deviation (SD). They were compared with the *t*-test, ANOVA (Kruskal-Wallis test) or median test, depending on what was most appropriate. A *p*-value <0.05 was considered to be statistically significant. The prevalences of the outcomes (Table 2) were compared between winter and summer athletes as well as between the different ventilation rates using adjusted odds ratio (aOR) with 95% confidence intervals (95% CI). Adjustments were made for the a-priori defined potential confounders age, sex, smoking habits, level of education, and the other variables in the model. Using logistic regression, FE_{NO} values and spirometry were compared between asthmatic and non-asthmatic athletes as well as between different ventilation rates. For this approach, FE_{NO}-values were dichotomized by 25 ppb according to the current guidelines [37,38], and spirometry values were dichotomized by 100% of the reference values [36]. This was considered to be appropriate, as it is expected that top athletes have respiratory functions much higher than the general population.

Table 2
Outcome definitions.

Definition	Question
Doctors' diagnosed asthma	Affirmative responses to the following two questions: "Have you ever had asthma?" AND "Was this confirmed by a doctor?"
Current wheezing	Affirmative responses to the following two questions: "Have you had wheezing or whistling in your chest at any time within the last 12 months?" AND "Have you had this wheezing or whistling when you did not have a cold?"
Current use of asthma medication	Affirmative response to the following question: "Are you currently taking any medicines including inhalers, aerosols or tablets for asthma?"
Allergic rhinitis	Affirmative response to the following question: "Do you have any nasal allergies, including hay fever?"
Atopic dermatitis	Affirmative responses to the following two questions: "Did you ever have an itchy rash that for at least six months got worse and better?" AND "Did this itchy rash occur in the last 12 months?"

3. Results

3.1. Study participants

The subjects' characteristics are shown in Table 3. Elite winter athletes were on average younger (mean age 23.5 vs. 27.8 years), were less likely to have a high education level (65% vs. 80%), to be smokers (2% vs. 14%), to exercise every day (70% vs. 85%) and to exercise only indoor (10% vs. 34%) when compared to elite summer athletes.

3.2. Questionnaire

Of the 548 German elite athletes included in this study 9% reported a current wheeze, 8% current use of asthma medication, 15% doctors' diagnosed asthma, more than a quarter allergic rhinitis, and 6% atopic dermatitis (Table 4).

The prevalence of current wheezing was statistically significantly lower in winter athletes than in summer athletes (6% vs. 12%; $p_{\text{Chi2}} = 0.007$) and there was a tendency for all defined asthma outcomes for winter athletes being less affected when compared to summer athletes. However, after adjusting for the potential confounders, there remained no statistically significant difference between winter and summer athletes. Regarding the ventilation rate achieved during competition athletes participating in high ventilation sports more frequently reported current wheezing (11.4% vs. 4.9%, $p_{\text{Chi2}} = 0.04$), current use of asthma medication (10.9% vs. 2.8%, $p_{\text{Chi2}} = 0.01$) and doctors' diagnosed asthma (18.1% vs. 8.4%, $p_{\text{Chi2}} = 0.01$) than athletes participating in low ventilation sports. The rates remained significant after adjusting for potential confounders with an approximate two-fold increased risk of doctors' diagnosed asthma, a three-fold increased risk of current wheezing or asthma medication and an even four-fold increased risk of asthma medication for athletes in high ventilation sports (Table 4).

Results remained the same after additionally adjusting for training days per week and training location.

3.3. Clinical measurements

Athletes with doctors' diagnosed asthma were not found to have impaired pulmonary function results at rest, but an approximate four-fold increased risk for elevated FE_{NO} -values was detected for these athletes (OR 3.59; 95% CI 1.16–11.11) (Table 5; Fig. 1).

4. Discussion

In this study, the prevalence of asthma in a representative sample of German elite winter and summer athletes engaged in different sport disciplines and representative of an entire country has been assessed using standardized instruments. The study allowed the assessment of differences in asthma prevalence between elite winter and summer athletes from a wide range of sport disciplines. Additionally, the asthma risk according to level of ventilation achieved during competition was investigated.

4.1. Competition season (winter vs. summer)

The results of this study both confirm and refute results of earlier studies. Among German winter athletes we found a prevalence of current wheezing that was lower than among German summer athletes and there was a tendency for all defined asthma outcomes for winter athletes being less affected when compared to summer athletes. However, after adjusting for the potential confounders this difference did not remain statistically significant. In conclusion, there was no association between the competition season and the asthma outcomes considered. So far, there has been only one other study published which compared the prevalence of asthma in elite winter and summer athletes of different sport

Table 3
Descriptive statistics of the elite athletes by competition season and ventilation rate.

	Competition season			Ventilation rate			
	Winter (N = 265)	Summer (N = 283)	p-value	Low (N = 143)	Interm (N = 53)	High (N = 352)	p-value
	m (SD)	m (SD)	t-test	m (SD)	m (SD)	m (SD)	ANOVA
Age (years)	23.5 (4.7)	27.8 (6.0)	<0.001	27.1 (7.2)	24 (3.9)	25.4 (5.3)	0.04
Height (cm)	177.1 (8.5)	178.2 (11.1)	NS	176.9 (9.5)	175.2 (10.0)	178.3 (10.0)	NS
Weight (kg)	72.8 (13.3)	74.4 (15.3)	NS	74.2 (16.1)	73.1 (12.3)	73.4 (13.9)	NS
	n (%)	n (%)	Chi ² -test	n (%)	n (%)	n (%)	Chi ² -test
Sex (male)	165 (62.5)	129 (45.6)	<0.001	85 (59.4)	23 (43.4)	186 (52.9)	NS
Education (≥ 12 years)	169 (64.8)	226 (79.9)	<0.001	100 (70.9)	33 (62.3)	262 (74.9)	NS
Ever smoker	6 (2.3)	49 (14.3)	<0.001	24 (16.9)	1 (1.9)	21 (6.0)	<0.001
Training days per week (Every day)	185 (70.1)	249 (85.4)	<0.001	94 (66.2)	34 (65.4)	297 (84.6)	<0.001
Training location (Only indoor)	26 (9.8)	97 (34.3)	<0.001	32 (22.4)	14 (26.9)	77 (21.9)	NS

Total number (N), Mean (m), standard deviation (SD), not statistically significant (NS), ANOVA (Kruskal-Wallis test), Intermediate (Interm.).

Table 4
Crude and adjusted risk estimates with corresponding odds ratios (OR) and 95% confidence intervals (95% CI) for two different regression models, each modeling all asthma outcomes.

	Prevalence n (%)	pChi2-value	cOR (95% CI)	aOR (95% CI)
Current wheeze				
Competition season:		0.007		
Winter (N = 265)	15 (5.7)		1	1
Summer (N = 283)	34 (12.4)		2.34 (1.24–4.41)	1.76 (0.87–3.54)
Ventilation rate:		0.04		
Low (N = 143)	7 (4.9)		1	1
Intermediate (N = 53)	2 (4.4)		0.88 (0.18–4.38)	1.10 (0.21–5.69)
High (N = 352)	40 (11.4)		2.48 (1.08–5.68)	2.30 (0.98–5.40)
Current use of asthma medication				
Competition season:		NS		
Winter (N = 265)	18 (6.8)		1	1
Summer (N = 283)	27 (9.8)		1.49 (0.80–2.77)	0.97 (0.48–1.98)
Ventilation rate:		0.01		
Low (N = 143)	4 (2.8)		1	1
Intermediate (N = 53)	3 (6.5)		2.42 (0.52–11.26)	2.87 (0.59–13.87)
High (N = 352)	38 (10.9)		4.23 (1.48–12.09)	4.46 (1.52–13.10)
Current wheeze or Current use of asthma medication				
Competition season:		0.02		
Winter (N = 265)	25 (9.5)		1	1
Summer (N = 283)	44 (16.1)		1.98 (1.18–3.32)	1.27 (0.71–2.28)
Ventilation rate:		0.005		
Low (N = 143)	9 (6.3)		1	1
Intermediate (N = 53)	3 (6.5)		0.92 (0.24–3.50)	1.20 (0.31–4.70)
High (N = 352)	57 (16.3)		2.68 (1.33–5.40)	2.78 (1.34–5.76)
Doctors' diagnosed asthma				
Competition season:		NS		
Winter (N = 265)	32 (12.2)		1	1
Summer (N = 283)	47 (17.1)		1.50 (0.92–2.43)	1.08 (0.63–1.88)
Ventilation rate:		0.01		
Low (N = 143)	12 (8.4)		1	1
Intermediate (N = 53)	4 (8.7)		1.04 (0.32–3.40)	1.11 (0.33–3.73)
High (N = 352)	63 (18.1)		2.40 (1.30–4.60)	2.32 (1.19–4.53)
Allergic rhinitis				
Competition season:		NS		
Winter (N = 265)	75 (28.5)		1	1
Summer (N = 283)	70 (25.8)		0.87 (0.60–1.28)	0.83 (0.53–1.28)
Ventilation rate:		NS		
Low (N = 143)	40 (28.6)		1	1
Intermediate (N = 53)	13 (28.3)		0.99 (0.47–2.06)	1.03 (0.48–2.22)
High (N = 352)	92 (26.4)		0.90 (0.58–1.39)	0.87 (0.55–1.38)
Atopic dermatitis				
Competition season:		NS		
Winter (N = 265)	15 (5.7)		1	1
Summer (N = 283)	19 (6.9)		1.23 (0.61–2.48)	1.37 (0.61–2.95)
Ventilation rate:		NS		
Low (N = 143)	9 (6.3)		1	1
Intermediate (N = 53)	4 (8.9)		1.44 (0.42–4.93)	1.31 (0.37–4.64)
High (N = 352)	21 (6.0)		0.94 (0.42–2.11)	0.82 (0.36–1.90)

cOR – crude Odds Ratio; aOR - Odds Ratio adjusted for age, sex, smoking habits, and level of education.

Table 5
Clinical measurements.

	Prevalence n (%)	pChi2-value	cOR (95% CI)	aOR (95% CI)
FE_{NO} ≥ 25 ppb				
Doctors' diagnosed asthma		0.02		
No (N = 140)	40 (29)		1	1
Yes (N = 16)	9 (56)		3.21 (1.12–9.22)	3.59 (1.16–11.11)
Ventilation rate:		NS		
Low (N = 50)	16 (32)		1	1
Intermediate (N = 23)	4 (17)		0.45 (0.13–1.53)	0.56 (0.15–2.09)
High (N = 84)	29 (35)		1.12 (0.53–2.36)	1.28 (0.56–3.0)
FEV₁/FVC_{ex} < 100% predicted				
Doctors' diagnosed asthma		NS		
No (N = 140)	69 (43)		1	1
Yes (N = 16)	5 (31)		0.61 (0.20–1.84)	0.66 (0.21–2.12)
Ventilation rate:		NS		
Low (N = 50)	19 (38)		1	1
Intermediate (N = 23)	11 (48)		1.50 (0.55–4.06)	2.48 (0.80–7.68)
High (N = 84)	36 (43)		1.22 (0.60–2.50)	1.90 (0.83–4.32)

cOR – crude Odds Ratio; aOR - Odds Ratio adjusted for age, sex, smoking habits, and level of education.

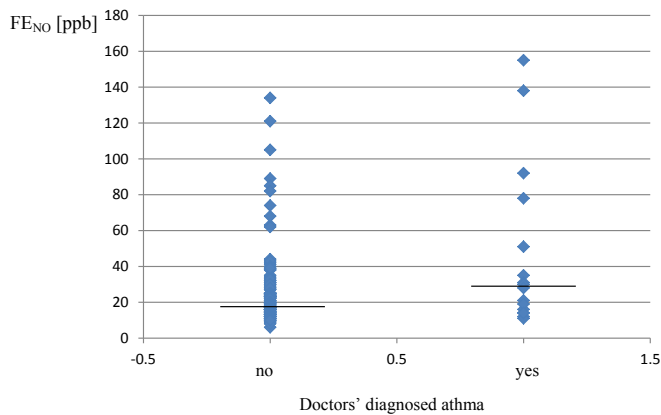


Fig. 1. FE_{NO} in athletes with and without doctors' diagnosed asthma.

disciplines [15]. This study is in contrast to our findings. Weiler et al. compared the 196 US athletes who participated in the 1998 Olympic Winter Games in Nagano (Japan) with the 699 US athletes who participated in the 1996 Olympic Summer Games in Atlanta (USA). In this study, comparing US elite winter athletes with US elite summer athletes, doctors' diagnosed asthma (22% vs. 15%), wheezing (12% vs. 10%), and current use of asthma medication (17% vs. 10%) appeared to be more common in winter than in summer athletes [14,15]. There are other studies which suggest that athletes who participate in winter sports suffer more frequently from asthma than those who are active in summer sports [8,9,39–44]. However, it should be noted that these studies are based on different sports and there are also studies demonstrating a high prevalence of asthma in summer athletes [5,14,22,45–47]. For example, swimmers seem to be more likely to have asthma than other competitive athletes, with up to 70% of elite swimmers diagnosed with asthma [42,48–50]. In our study 37% of the swimmers reported doctors' diagnosed asthma.

Ventilation rate achieved during competition: Considering the different sport disciplines, our study confirmed that athletes engaged in high ventilation sports have a higher prevalence of asthma in comparison with athletes engaged in low ventilation sports. An approximate two-fold increased risk of doctors' diagnosed asthma, three-fold increased risk of current wheezing or asthma medication and an even four-fold increased risk of asthma medication were detected for athletes performing at the highest ventilation level. Similar results have been reported by other authors: consistently, the same sport disciplines appear to have an increased risk of asthma [17,21,51–54]. An advantage of our study was that the ventilation rate achieved during competition – which is known to be an important factor in the pathogenesis of asthma in athletes – was directly taken for classification of sport disciplines. Most other studies used endurance level for classification. Since the World Anti-Doping Committee (WADA) and the International Olympic Committee (IOC) removed the need to document asthma by lung function tests before the use of the inhaled β_2 -agonists salbutamol, salmeterol, formoterol and inhaled corticosteroids between 2010 and 2012, incongruence of asthma treatment with asthma diagnosis might be an issue [42]. However, there is high evidence that β_2 -agonists within the controlled concentrations do not improve exercise performance in highly trained athletes [42,55–64]. In contrast, in recreational athletes there seems to be an effect on performance [65,66].

In conclusion, our study shows that especially athletes performing high ventilation sports are at an increased risk of having asthma. There was no statistically significant difference between

winter and summer athletes. These findings might be explained by the pathogenesis of asthma in athletes [67,68]. During exercise, ventilation rises considerably, reaching up to 280 L per minute. Both winter and summer athletes are exposed to unfavorable environmental conditions that may aggravate the effects of intense exercise [22,69]. Winter athletes are exposed to large volumes of cold air, summer athletes to allergens in the air and high levels of ozone, and swimmers to chlorine and its metabolites [70–72]. In low ventilation sports, ventilation is increased for only short periods of time, but in high ventilation sports this occurs over longer periods. When the ventilation level exceeds about 30 L per minute there is a shift from nasal breathing to combined mouth and nasal breathing, which leads to incompletely conditioned and cleaned air reaching lower airways [45]. This results in mucosal injury which may lead to chronic inflammation and thus contribute to the development of asthma [5]. Furthermore, intense exercise leads to the activation of the parasympathetic nerve system – especially in endurance athletes – which aggravates bronchoconstriction [73]. Suppression of the immunological protection might lead to recurrent infections of the upper airway. This could contribute to the development of asthma in athletes [3,12].

4.2. Clinical measurements

Despite a relatively large sample of winter athletes additionally examined with FE_{NO}-levels and lung function (N = 174) the number of athletes with doctors' diagnosed asthma (n = 16) in this subgroup was small. Thus, the interpretation of these results remains speculative. In our study, there was no statistically significant difference in the lung function test results between asthmatic and non-asthmatic athletes at rest. The aim of the clinical measurements was to assess asthma control rather than verify the reported diagnosis. The asthmatic athletes studied continued to take their asthma medication. Stenfors et al. have reported that lung function testing shows a quick decrease if asthmatic athletes stop taking their asthma medication [9]. Our study has found asthmatic athletes demonstrate no impaired pulmonary function at rest. One might argue that the cut-off point for the spirometry was not adequate. However, the use of continuous data did not change the results. On the other hand, our study showed an approximate four-fold increased risk for elevated FE_{NO}-values for asthmatic athletes. This might suggest an insufficient control of the asthma status and might explain asthma symptoms during exercise despite normal lung function test results at rest [74]. Unfortunately, we did not implement an asthma control questionnaire [75]. This suboptimal asthma control might be due to insufficient medication or insufficient compliance.

Some limitations of our study should be mentioned: Diagnosis of asthma relied on what was self-reported, no objective measurement of asthma was made. The majority of athletes included in this study were medically taken care of at the Department for Prevention, Rehabilitation and Sports Medicine, Technical University of Munich. This is why we assume that the self-reported outcomes in our study are reliable. The obtained data neither showed whether athletes already suffered from asthma when starting their career, nor whether asthma was developed by exercising at a higher performance level. In our study, conditions during competition were used for classification (i.e. competition season and ventilation rate achieved during competition). Interpreting our data, it should be considered that conditions during competition often differ from conditions during training, elite athletes perform training in winter as well as in summer, and the requirement concerning ventilation differs between training sessions. The present study did not incorporate objective measurements of specific environmental conditions related to each type of sport [76]. Further studies should

include these measurements in order to define further risk factors for the development of asthma in athletes. A differentiation between chronic asthma and exercise induced bronchoconstriction was not made.

5. Conclusions

In conclusion, our study supports earlier evidence that athletes involved in high ventilation sports are at an increased risk to suffer from asthma. In contrast the competition season (winter vs. summer) had no impact on the frequency of asthma in our study. This knowledge should be used when working with elite athletes. Especially for athletes involved in high ventilation sports, asthma prevention should be performed from the beginning of their career. This could be practiced during training sessions. Airway-irritating environmental conditions should be considered [50,77,78]. Among winter athletes elevated FE_{NO}-values suggested suboptimal control of the disease. Currently used methods such as spirometry may not be sensitive enough to assess asthma control in athletes during activity [79].

Conflicts of interest

None.

Role of the funding source

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