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Asthma prevalence in Olympic summer athletes and the general population: an analysis of three European countries

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Key terms

Athletics, endurance, epidemiology, exercise, respiratory

Abbreviations

AQUA: Allergy Questionnaire for Athletes

ECRHS: European Community Respiratory Health Survey

GA^{2}LEN: Global Allergy and Asthma European Network

WADA: World Anti-Doping Committee

ABSTRACT

Background: Some studies have shown a higher prevalence of asthma in elite athletes as compared to the general population. It is inconclusive to what extent certain sport categories are especially affected. The present study offered a unique opportunity to assess these differences in asthma prevalence in the general population and elite summer athletes from a wide range of sport disciplines across various geographical areas.

Methods: Cross-sectional data for 1568 general population participants from the European Community Respiratory Health Survey II and 546 elite athletes from the Global Allergy and Asthma European Network Olympic study from three European countries were analyzed. Using logistic regression, the asthma risks associated with athlete sport practice, endurance level and aquatic sport practice, respectively, were investigated.

Results: Athletes in the highest endurance category had increased risk of doctor-diagnosed asthma (OR 3.5; 95% CI 1.7-7.5), asthma symptoms (OR 3.0; CI 1.5-6.0) and asthma symptoms or medication use (OR 3.5; CI 1.8-6.7) compared to the general population. Aquatic athletes were at increased risk of doctor-diagnosed asthma (OR 2.0; CI 1.1-3.9), asthma symptoms (OR 2.6; CI 1.3-5.0) and asthma symptoms or medication use (OR 2.3; CI 1.2-4.4) when compared to individuals not involved in aquatic sports. Regarding the entire athlete population, no increase in asthma was found when compared to the general population.

Conclusions: Practice of very high endurance and aquatic sports may be associated with increased asthma risks. Athlete participation as such showed no association with asthma risk.

INTRODUCTION

Asthma is a chronic disorder affecting up to 300 million people worldwide [1]. Prevalence and incidence have been increasing over the past decades [2,3]. This is a serious public health concern, especially as the risk factors for asthma are not fully understood. Some studies suggest that asthma may be more prevalent in elite athletes than in the general population with up to 10% being affected, making it the most common chronic disorder affecting this professional group [4,5], though the evidence so far is limited. Asthma is not only a serious health risk for elite athletes, but additionally its detrimental effects are magnified since asthma can drastically interfere with athletic performance [6].

Within the group of elite athletes, the prevalence of asthma may differ by sport discipline [6,7]. Athletes who participate in endurance sports seem to be at an increased risk for asthma than other athletes, possibly due to the vigorous activity and regularly repeated higher ventilation rates over prolonged periods of time associated with their discipline [7,8]. Swimmers might also be at high risk, as previous studies have suggested that pool athletes are predisposed to airway dysfunctions, including asthma, due to their exposure to irritants such as chlorine and derived by-products in the pool environment [9,10]. This international cross-sectional study offered a unique opportunity to assess differences in asthma prevalence between the European general population and European summer athletes from a wide range of sport disciplines across various geographical areas. Furthermore, differences in asthma risk among athletes participating in sports of various endurance levels as well as aquatic sports were compared to the general population.

METHODS

Study Design

Two independent cross-sectional studies were conducted to assess the prevalence of asthma and respiratory disorders; the first among the general population from Norway, Germany and Spain and the second among the European summer Olympic athletes representing these 3 countries.

Study participants

General Population

Data for the general population (n=1568) were available through the European Community Respiratory Health Survey (ECRHS) II, conducted in the early 2000s (response 65.3% of those having participated in ECRHS I). The aim of ECRHS was to assess the prevalence, incidence, determinants and management of asthma in the adult population in various European countries. ECRHS was approved by local ethics committees and their methods have been published in detail elsewhere [11].

For the present analysis data were used of Norwegian (1 center), German (2 centers) and Spanish (5 centers) participants of less than 45 years of age, who formed part of the random sample of ECRHS II in 2002. From the ECRHS II questionnaire, we extracted data regarding asthma, exercise frequency and smoking habits.

Elite Athletes

Data for the elite athletes (n=546; response 65.2%) were available from a study on participants of the 2008 Beijing Olympics, conducted within the framework of the Global Allergy and Asthma European Network (GA^2LEN) [12], which assessed allergic and respiratory illnesses among Olympic participants. The study used the

Allergy Questionnaire for Athletes (AQUA) [13]. From the GA^{2}LEN Olympic study we extracted data regarding asthma, exercise frequency, level of endurance, and type of sport.

In Norway, Germany and Spain, additional questions regarding asthma and smoking habits were extracted from the ECRHS questionnaire. The common use of the ECRHS questions in both study populations allowed for comparison between the two groups. GA^{2}LEN was approved by local ethics committees and their methods have been published in detail elsewhere [12].

Exposure definitions

Three possible exercise-related exposures for asthma were defined:

1. Elite Athlete population

The first exposure was defined as whether or not the individual was a member of the elite athlete population, as compared to the general population.

2. Endurance Level

The second exposure was defined as sport endurance level. We categorized the sports based on the level of endurance as defined by Alaranta et al. [14]. For those sports included in the dataset, but not in the classifications by Alaranta et al. (badminton, modern pentathlon, tennis and weightlifting, n=18) we assigned a category based on a priori knowledge of the sport. The classifications are as follows:

- General population (reference level)
- Low / middle level of endurance: riding, gymnastics, taekwondo, table tennis, shooting, archery, sailing, badminton, modern pentathlon
- High level of endurance: basketball, hockey, football, handball, volleyball, fencing, judo, karate, wrestling, tennis, weightlifting

- Very high level of endurance: aquatic sports, track and field athletics, canoeing, cycling, rowing, throwing

3. Aquatic Sports

The third exposure was defined as participation in aquatic sports:

- Non-aquatic: general population, all other sports, including those taking place in natural water environments (reference level)
- Aquatic sports: sports taking place in swimming pools typically treated with chlorinated or other chemical disinfectants

Outcome definitions

The following asthma outcome variables were defined as a positive response to the following questionnaire items:

Doctor-diagnosed

- Have you ever had asthma, AND was this confirmed by a doctor?

Asthma Symptoms

- 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?

Asthma symptoms or medication

- [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?] OR [Are you currently taking medicines for asthma]

The second and the third outcomes were considered important as they take into consideration the potential difference in doctors' diagnoses and medication use, respectively, between the general population and elite athletes.

Potential confounders

Possible confounders that were considered include age, sex, smoking status (never, ever, current), country of origin (Norway, Germany, Spain), and frequency of exercise. Data on air pollution exposure, allergy and family history of asthma were not available.

As the two questionnaires assessed frequency of exercise differently, respective variables were re-coded into comparable categories (minimal, once per week, 2-3 times per week, 4-6 times per week, daily). The general population categories of “never”, “less than one time per month” and “once per month” were combined into the category “minimal”. Further, the athlete category “≤ 3 times per week” was re-coded into “2-3 times per week”, based on the assumption elite athletes probably practice at least twice per week.

Statistical analysis

All analyses were performed using R (version 2.14.1). Three crude and three adjusted logistic regression models were developed to assess the risk of having asthma, according to the above-described outcome definitions. Risk estimates for the three defined asthma outcomes were modeled on the following exposure comparisons: athlete versus non-athlete (Model 1), level of endurance (Model 2) and aquatic versus non-aquatic sports (Model 3). For Models 1 and 2 the general population was used as reference category, while for Model 3 the general population and athletes not participating in an aquatic sport were included in the reference category. Adjustments were made for above-mentioned potential confounders.

Sensitivity analyses

To check the robustness of the models, age restriction to participants below the median age, restriction to never-smokers, and stratification by country were performed. As an additional sensitivity analysis we added random-effects terms to each model to investigate the between-country variance. Furthermore, to disentangle the effect on asthma due to endurance and aquatic sports, respectively, aquatic sports athletes were removed from the category ‘very high endurance’, to form a separate level in the categorical variable ‘endurance level’.

RESULTS

Descriptives

The demographic characteristics of study participants are summarized in Table 1.

Table 1. Descriptive statistics of the general population and the elite athlete population.

Variable	General Population (n = 1568)	Athletes (n = 546)
Age (years)		
Mean (SD)	37.5 (4.4)	27.0 (5.5)
Male n (%)	772 (49.2)	248 (45.7)
Country n (%)		
Germany	309 (19.7)	291(53.5)
Norway	337 (21.5)	77 (14.1)
Spain	922 (58.8)	176 (32.4)
Frequency of Exercise n (%)		
Minimal	761 (50.0)	-
1x per week	255 (16.8)	-
2-3x per week	336 (22.1)	7 (1.3)
4-6x per week	87 (5.7)	113 (20.8)
Daily	82 (5.4)	422 (77.9)
Smoking n (%)		
Never	562 (35.9)	469 (84.5)
Former	322 (20.6)	41 (7.7)
Current	682 (43.5)	20 (3.8)

Participants from the general population were on average older (mean age 37.5 vs. 27.0), were much more likely to be smokers (64% vs. 19% ever smoking), and were much less likely to exercise regularly (33.2% vs. 100% exercise frequency ≥2 times per week) when compared to elite athletes.

Logistic regression models

After adjustment for potential confounders, elite athletes showed neither a statistically significant increased risk of doctor-diagnosed asthma, asthma symptoms nor of asthma symptoms and medication use, when compared to the general population (Table 2, Model 1).

Table 2. Crude and adjusted risk estimates with corresponding odds ratios (OR) and 95% confidence intervals (95% CI) for three different logistic regression models, each modelling all three asthma outcomes.

Outcome	Doctor-diagnosed[a]			Symptoms[b]			Symptoms or medication[c]		
		OR 95% CI			OR 95% CI			OR 95% CI	
	n (%)	Unadjusted	Adjusted[d]	n (%)	Unadjusted	Adjusted[d]	n (%)	Unadjusted	Adjusted[d]
Model 1									
Elite athlete:									
General population	118 (7.5)	1	1	207 (13.4)	1	1	223 (14.4)	1	1
Elite Athlete	90 (17.2)	2.5 (1.9-3.4)	1.7 (0.9-3.3)	67 (12.9)	0.96 (0.71-1.29)	1.4 (0.7-2.6)	88 (16.9)	1.2 (0.9-1.6)	1.6 (0.9-2.8)
Model 2									
Endurance level:									
General population	118 (7.5)	1	1	207 (13.4)	1	1	223 (14.4)	1	1
Low-middle	9 (9.7)	1.3 (0.6-2.7)	1.1 (0.4-2.6)	4 (4.3)	0.3 (0.1-0.8)	0.5 (0.2-1.5)	6 (6.5)	0.4 (0.2-1.0)	0.6 (0.2-1.7)
High	22 (11.2)	1.5 (1.0-2.5)	1.1 (0.5-2.4)	13 (6,7)	0.5 (0.3-0.8)	0.7 (0.3-1.7)	19 (9.7)	0.6 (0.4-1.1)	0.9 (0.4-1.9)
Very high	59 (25.5)	4.2 (3.0-6.0)	3.5 (1.7-7.5)	50 (21.6)	1.8 (1.3-2.5)	3.0 (1.5-6.0)	63 (27.4)	2.2 (1.6-3.1)	3.5 (1.8-6.7)
Model 3									
Aquatic sports:									
No[e]	192 (9.5)	1	1	259 (12.9)	1	1	294 (14.7)	1	1
Yes	16 (26.2)	3.4 (1.9-6.1)	2.0 (1.1-3.9)	15 (24.2)	2.2 (1.2-3.9)	2.6 (1.3-5.0)	17 (27.9)	2.2 (1.3-4.0)	2.3 (1.2-4.4)

[a] Have you ever had asthma, AND was this confirmed by a doctor?

[b] 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?

[c] [Are you currently taking medicines for asthma] OR [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?]

[d] Adjusted for age, sex, smoking, country of origin and frequency of exercise

[e] Includes the general population.

Among the athlete population, participating in a sport characterized by a very high endurance level was associated with a statistically significant increased risk of doctor-diagnosed asthma (OR 3.5; 95%CI 1.7-7.5), asthma symptoms (OR 3.0; 95%CI 1.5-6.0) and asthma symptoms or medication (OR 3.5; 95%CI 1.8-6.7) when compared to the general population (Table 2, Model 2). Participation in aquatic sports was associated with a statistically significant increase in risk of doctor-diagnosed asthma (OR 2.0; 95%CI 1.1-3.9), asthma symptoms (OR 2.6; 95%CI 1.3-5.0) and asthma symptoms or medication (OR 2.3; 95%CI 1.2-4.4) when compared to non-aquatic sports and the general population (Table 2, Model 3). All models were robust to performed sensitivity analyses; age restriction, restriction to non-smokers, the disentanglement of aquatic sports athletes from the 'very high endurance' level, and stratification by country. Specifically regarding the homogeneity of the results across the different countries, for all models in Table 2, introducing random-effects terms never yielded an intraclass correlation coefficient above 0.2%, indicating a very low between-country variance (data not shown).

DISCUSSION

This study allowed for the assessment of differences in asthma prevalence in two diverse populations; summer athletes from a wide range of sport disciplines and an established general population, both originating from countries that well represent European climate and other geographical differences. Additionally, the asthma risk according to level of endurance and aquatic sport participation were investigated. A positive association between exposure to the highest level of endurance and an increased risk of all three defined asthma outcomes was found. Athletes within this group had, with regards to all three asthma outcomes, an approximately three times higher risk when compared to the general population. Similarly, an approximate twofold increase in risk of having asthma symptoms was found among athletes performing aquatic sports compared to all other athletes and the general population. However, with respect to all three asthma outcomes, our results suggest no statistically significant risk increase of asthma among the entire athlete population when compared to the general population.

These results both confirm and refute results of earlier studies. The null finding of this analysis, with respect to the difference in asthma risk between the general and athlete populations, is similar to an Australian study [15] but contrasting to the German GA^{2}LEN study [16]. The latter difference might potentially be explained by higher medical surveillance among our general population or lower medical surveillance among our athlete population. Thereto, the German study applied different adjustments and used a different general population compared with present analysis. Our null finding might also result from a healthy worker effect in the athlete population, if those athletes most affected by asthma are no longer participating in their sport. Although the ECRHS II should contain a representative number of symptomatic subjects [17,18], defining ECRHS II participants as the general population might have introduced selection bias. It is possible that a retention bias led to a disproportionate number of individuals with asthma from ECRHS I agreeing to continue into ECRHS II. This potential bias would lead to an underestimation of the asthma risk based on the comparison between the athlete population and the ECRHS II population.

Based on the German results of the GA^2LEN study, which used a different reference population, an approximate two-fold increased risk of doctor-diagnosed asthma and asthma symptoms or asthma medication was detected for athletes performing at the highest level of endurance [16]. Our study demonstrated risk estimates in the same direction, although of even higher magnitude (OR=3.5; 95% CI 1.7-7.5 and OR=3.5; 95% CI 1.8-6.7). Similarly, Parsons et al. found that athletes in high endurance sports were 23% more symptomatic than athletes in lower endurance sports [19]. This increased prevalence in elite endurance athletes has been attributed to the repeated physical strain causing epithelial damage, increasing inflammation in the respiratory mucosa, as well as to prolonged hyperventilation and increased exposure to inhalant allergens and irritants during endurance training and competition [8,9,17,20] (add Jerning et al. 2013)]. Regarding two of our asthma outcomes - asthma symptoms and asthma symptoms or asthma medication - a U-shaped relationship was found with increasing levels of endurance. A similar relationship, albeit strictly negative, was found in another study based on the ECHRS II survey [21], which examined the influence of frequency and duration of physical activity on bronchial hyper-responsiveness, an asthmatic precursor [22,23]. Thus, evidence suggests that physical activity, and to a certain degree also moderate endurance exercise, might induce a protective effect against asthma and its precursors [24].

The approximate twofold increased risk for asthmatic symptoms in aquatic athletes found in our study has been similarly shown in previous studies, including a meta-analysis of six studies showing that swimmers have increased odds for asthma compared to other competitive athletes (OR=2.57; 95% CI 1.87-3.54)[10][1]. Additionally, Stadelmann et al. found that over 80% of a sample of elite swimmers self-reported respiratory problems [25]. Furthermore, emerging evidence suggests that in addition to inhalation, skin exposure to allergens and irritants such as chlorine may be linked to the pathogenesis of asthma, which is important to consider in the context of swimmers [26].

Strengths of this study include the relatively large sample sizes and geographical variation of the study populations. Moreover, this study takes into account the assumed regional differences in asthma prevalence [27-29] by using data of ECRHS II from Norway, Germany and Spain, and thus covers diverse geographic regions of Europe. However, our mixed-effects models showed a between-country variance close to zero and stratification by country did not change reported results significantly, suggesting any regional differences in our study population to be negligible. Finally, the geographical representativeness and the large study population increase the power and generalizability of our study findings.

Our results are based on cross-sectional self-reported data, which rules out any causal inference from the study findings. Moreover, data for the athletes and the general population originated from two different source studies (ECRHS II and GA^{2}LEN) that were performed nearly a decade apart in time. Defining ECRHS II participants as the general population might have introduced selection bias, as ECRHS II participants are unlikely representative of the entire adult population of Norway, Germany and Spain. Furthermore, taking into account the mentioned increase in the prevalence of asthma during the latest years [3,4,8,27], the temporal gap between the two studies might to some extent have weakened the comparability of the two study populations. Additionally, the mean age of the two study populations differed by approximately ten years. Sensitivity analyses, however, did not change our main results; age-restriction of the general population, only using those below the median age, yielded estimates in the same direction (data not shown). Further sensitivity analysis showed that inclusion of smokers into the model did not lead to biased results, as estimate direction and magnitudes remained relatively consistent after the exclusion of former and current smokers. The cross-sectional questionnaire data also did not include information on some potential confounders and effect modifiers, including air pollution, allergy prevalence, and family history of asthma and allergies, all of which could have influenced the prevalence of asthma in the two populations. Additionally, no marker for socioeconomic status was included in the analysis. A similar study comparing German Beijing Olympic athletes with a German general population showed that the level of education was generally higher in the athlete population as compared to the general population [16]. If higher level of education in our population in turn was associated with, for example, a lower exposure to passive smoke or ambient air pollution earlier in life, the comparison between the two populations in our study could be confounded.

As earlier studies have demonstrated that athletes have a very high degree of medical surveillance [16,30], risk estimates of doctor-diagnosed asthma modeled on the comparison of athletes and non-athletes might have been biased due to a differential misclassification of outcome. Further, based on the assumption that the athlete population has higher health awareness than the general population, a lower degree of recall bias in the assessment of asthma symptoms and medication use should be expected in the athlete population. Thus, also risk estimates modeled on the comparison of the two populations might have been biased due to differential misclassification of outcome. Finally, inadequate diagnosis and potential incongruence of asthma treatment with asthma diagnosis in athletes might be an issue since the World Anti-Doping Committee (WADA) and the International Olympic Committee removed the need to document asthma by lung function tests before the use of inhaled β2-agonists in 2009 [4]. However, the larger body of evidence suggests that β2-agonists within the controlled concentrations have no ergogenic effects and do not improve exercise performance [4,31,32].

Although mostly based on cross-sectional studies, there is an increasing body of evidence suggesting that participation in very high-level endurance sports or aquatic sports is associated with an increased risk of asthma and asthma symptoms. To further test this association and to gain information on causality, we suggest for future research the use of a cohort study design.

Regarding implications for practice, we hope that our findings eventually will increase awareness among physicians about asthma risk associated with high endurance and aquatic sports. This in turn might lead to higher medical surveillance of elite athletes performing high endurance and aquatic sports. Additionally, preventive asthma tests in early life may help guide adolescents in their choice of sport.

CONCLUSIONS

Our study supports earlier evidence that practice of very high endurance sports and aquatic sports may be associated with increased risks of asthma among athletes. The excess risk is possibly attributed to high frequency of repeated physical strain and excessive ventilation and exposure to allergens and irritants in swimming pools, respectively. With respect to all three asthma outcomes, no increased risk was found among athletes when compared to the European general population, suggesting an approximately similar medical surveillance and treatment of the two.

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Author contributions

Jacob Burns, Catherine Mason, Natalie Mueller and Johan Ohlander shared equally in the conception and completion of the statistical analysis, and drafting the manuscript; thus, if possible, these authors should all be stated as first authors. Katja Radon contributed to and coordinated the drafting of the manuscript. Jan-Paul Zock made valuable contributions to the analysis and manuscript. All authors read, contributed to, and approved the final manuscript.

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