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RESEARCH ARTICLE

Aeroallergen sensitization in Lebanese asthmatic children: the results of a cohort national study

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Abstract

Atopic asthma is characterized by the presence of sensitization to common aeroallergens, which tends to have a worse prognosis than non-atopic asthma. The objectives were to determine the prevalence of aeroallergens sensitization in the Lebanese pediatric asthmatic population and determine the relationship between allergens sensitization (indoor and outdoor) and age, area of residence and altitude. A sample, consisting of 919 asthmatic children (aged 1 to 18 years, from 2010 until 2017), underwent skin prick testing (SPT) with 21 common allergens: 5 grasses (cocksfoot, sweet vernal-grass, rye-grass, meadow grass, timothy), Parietaria, olive, *Dermatophagoides pteronyssinus* and *Dermatophagoides farina* (DP-DF), dog and cat dander, *Alternaria longipens, Aspergillus fumigatus* and *nidulans*, Cupressaceae, pine, German cockroach, and 4 cereals (oat, wheat, barley, maize). Seven hundred fifty-two patients had positive SPT. The distribution of sensitization was as follows: DP-DF 59%; 5 grasses 34%; 4 cereals 33.9%; cat 29.9%; Alternaria 27.9%; Parietaria 23%; dog 21.9%; olive 20.5%; Aspergillus mix 18.6%; Cupressaceae 18.2%; pine 17%; cockroach 15.3%. House dust mites sensitization was frequent at lower altitude (< 900 m) (56.3%) and in the whole country (a median prevalence of 53.05%) except for the Beqaa region (negative HDM in 82.4%). Non-atopic asthma was more frequent in early childhood (40.5% at 1–4 years vs 11.2% at 11–18 years). The sensitization rate increased with age, starting at 5 years. Higher age (aOR = 1.24) and altitude less than 900 m compared with ≥ 900 m (aOR = 2.03) were significantly associated with the presence of aeroallergens in children. House dust mites and grasses are the most common allergens in Lebanese asthmatic children. Non-atopic asthma is more frequent at early age. Lebanese children with asthma showed a polysensitized pattern starting at 5 years.

Keywords Asthma · Children · Allergens · Sensitization

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Introduction

Pediatric asthma is a chronic disease with a huge health, social, and economic burden worldwide. Although several asthma phenotypes have been recognized, the most common asthma classification in pediatrics remains atopic and non-atopic (Arroyave et al. 2016). Non-atopic asthma is the most prevalent phenotype during infancy and early childhood where the factors implicated in airways inflammation are not allergens but viral infections, irritants, exercise, or others (Arroyave et al. 2016; Jurca et al. 2017). Atopic asthma is characterized by the presence of sensitization to common aeroallergens (Arroyave et al. 2016), although the exact relationship between sensitization and asthma is much more complicated than a one-cause relationship (Arshad et al. 2001; Kaleyias et al. 2002; Şahiner et al. 2012). Allergen exposure increases airway inflammation, triggering exacerbations or causing uncontrolled asthma (Arroyave et al. 2016). Positive specific immunoglobulin E (IgE) and/or skin prick tests (SPTs) confirm the presence of atopy and identify the allergen responsible for IgE-mediated disease (Şahiner et al. 2012).

The worldwide geographical distribution of aeroallergens (climate change, pollution, altitude, and diverse human activities) can affect the allergens' concentration and distribution (Ozkaya et al. 2015).

Epidemiologic data, besides determining the prevalence of asthma, are very helpful in understanding trends and risk factors, which will allow devising strategies for the prevention and control of the disease. The last three decades have shown an increase in the prevalence of asthma around the world. The prevalence of childhood asthma in the Middle East countries was recently reviewed: it is lower than in many developed countries (Mirzaei et al. 2017).

Lebanon is a country in the Middle East with a Mediterranean climate. Its geography results in warm and humid weather along the coast and cold and rainy weather in the mountains. It has a large botanic diversity with more than 2600 pollen species (Bazarbachi et al. 2014). The most common pollens detected in the air are cupressaceae, grasses, Parietaria, and oleaceae (Bazarbachi et al. 2014). Until now, no data has been reported on the prevalence of aeroallergen sensitization in the Lebanese asthmatic children. The aim of this study is to determine the type and number of sensitizations to aeroallergens (based on SPT results) in the Lebanese asthmatic pediatric population according to age, gender, area of residence, and altitude.

Materials and methods

Patients

This is an observational study performed on Lebanese children aged 1 to 18 years. The sample was chosen from a referral center for pediatric asthma in Lebanon, the Asthma Center of the Childhood Protection and Care Association in Beirut, which provides free medical care to asthmatic children from all over the country, as well as from private asthma clinics. The period of evaluation was over 7 years, from 2010 until 2017. The ethics committee at the Notre Dame des Secours University Hospital approved the study protocol.

The diagnosis of asthma was established clinically by pediatric pulmonologists based on the presence of asthma-related symptoms (chronic wheezing, cough, and dyspnea) (Hallit et al. 2018a, b, c, 2017a, b) and confirmed by spirometry on patients old enough to cooperate.

The patients' area of residence was recorded and classified according to the five main regions of Lebanon: Beirut, North Lebanon, and South Lebanon, which are mainly coastal areas, Mount Lebanon, a mountainous region with relatively high altitude, and the Beqaa valley, an inland area with a continental climate. To study the influence of altitude on the pattern of allergen sensitization, we divided patients' areas of residence into two groups according to the estimated altitude: higher or lower than 900 m. Altitude data were obtained from the municipalities' available database ("Localiban: Centre de ressources sur le developpement local du liban. Municipality 2016. Available at: http://www.localiban.org/article787.html,"). Knowing that the highest inhabited village in Lebanon is at 1800 m and that the average altitude of the country is of about 1000 m above sea level, we decided to take a general limit of 900 m to study the influence of altitude on the pattern of allergen sensitization in Lebanon.

Allergens were also divided into two groups: indoor (I) or outdoor (O) allergens. Indoor allergens consisted of house dust mites (HDM), Aspergillus, Alternaria, cat and dog dander, and German cockroach while outdoor allergens included grasses, cereals, pine, olive, Cupressaceae, and Parietaria (Sheehan and Phipatanakul 2016).

Skin prick tests

SPTs were performed on all the patients as part of their clinical care using standard allergen extract (Stallergens, Antony, France) on the inner side of the forearm. A panel of 21 aeroallergens was used: 5 grasses (cocksfoot, sweet vernal-grass, rye-grass, meadow grass, timothy)(G), Parietaria (P), olive (O), the HDM *Dermatophagoides pteronyssinus* (DP) and *Dermatophagoides farinae* (DF), dog and cat danders (D and C), *Alternaria longipens* (Al), *Aspergillus fumigatus* and *nidulans* (As), Cupressaceae (Cu), pine (Pi), German cockroach (GC), 4 cereals (oat, wheat, barley, maize) (Ce).

A histamine solution (10 mg/mL) was used as positive control and a 50% glycerol saline solution as negative control. Reactions were read after approximately 20 min. SPT reactions were considered positive if the mean wheal diameter was > 3 mm (Kaleyias et al. 2002).

Statistical analysis

Data entry and analysis were performed using SPSS statistical software, version 23. A p value less than 0.05 was considered significant. Descriptive statistics were calculated for all study variables. This includes the mean and standard deviation for continuous measures, counts, and percentages for categorical variables. We divided the patients into 3 groups according to their age and we determined the prevalence of aeroallergen sensitization in each group. We studied the relationship between the prevalence of each allergen and the following variables: age, area of residence, and altitude (more or less than 900 m). According to the number of positive allergens, we also calculated the percentage of monosensitized and polysensitized children in each group. The polysensitized patients were defined as having SPT positive to more than 5 aeroallergens. Another variable was created (presence vs absence of aeroallergens); the presence of aeroallergens was defined as the presence of at least one aeroallergen in the child.

The chi-square test was used for comparison between categorical variables. The ANOVA test was used to compare three means or more. Two multivariable logistic regressions were conducted taking the presence vs absence of aeroallergens as the dependent variable. In the first model, age was taken as a continuous variable, whereas in the second model, it was taken as a categorical one. Variables showing a $p < 0.2$ in the bivariate analysis were taken in the final model as independent variables to decrease the confounding variables effect as much as possible. A $p < 0.05$ was considered statistically significant.

Results

A total of 971 patients were initially evaluated. Of these, 52 children were excluded for having invalid SPT results due to dermographism. Nine hundred nineteen children (male/female ratio of 2 and mean age of 8.1 ± 3.5) had a valid SPT and were therefore included in our study. Table 1 summarizes the characteristics of the study population.

Among the 919 children enrolled in the study, positive SPTs were identified as follows: DP in 58.8%, DF 57.2%, G 33.8%, Ce 33.6%, C 30%, Al 28%, P 23%, D 21.9%, O 20.5%, As 18.6%, Cu 18%, Pi 17%, GC 13.3%.

HDM was the most common allergen followed by grasses, cereals, and cat dander (Table 2 and Fig. 1).

Some descriptive statistics about the five regions in Lebanon concerning temperature, altitude, and humidity are also summarized in Fig. 2.

The sensitization rate to HDM increased with age (χ^2 = 69.13; $p < 0.001$). Sensitization to cat and dog dander, olive, and Parietaria also showed an increasing trend with age (cat $\chi^2 = 32.69$; $p < 0.001$; dog $\chi^2 = 13.5$; $p = 0.001$; olive χ^2 = 18.96; $p < 0.001$; Pretoria $\chi^2 = 22.84$; $p < 0.001$). Sensitization to pine, Alternaria, 4 cereals, and grasses allergens was more prevalent in the 5–10 years age group (P $\chi^2 = 28.28$; $p < 0.001$; Al $\chi^2 = 31.13$; $p < 0.001$; Ce χ^2 = 26.56; $p < 0.001$; G $\chi^2 = 6.39$; $p = 0.041$), while sensitization to Cupressaceae, Aspergillus, and German cockroach did not show any correlation with age (Cu $\chi^2 = 2.07$; $p = 0.354$; As $\chi^2 = 4.51$; $p = 0.105$; G.C. $\chi^2 = 5.48$; $p = 0.065$).

Table 1 Characteristics of the study population

	1–4 years	5–10 years	11–18 years	Total
Age, years				
Mean ± SD	3.45 ± 0.81	7.11 ± 1.76	12.86 ± 1.58	8.12 ± 3.51
Median	4	7	13	8
Gender, % (*n*.)				
Male	65.2% (86)	69.6% (378)	62% (152)	67% (616)
Female	34.8% (46)	30.4% (165)	38% (93)	33% (303)

The distribution of allergen sensitization according to the five different areas of Lebanon showed that high statistical significance was found for sensitization to HDM (χ^2 = 82.76; $p < 0.001$), 4 cereals ($\chi^2 = 55.11$; $p < 0.001$), and grasses ($\chi^2 = 47.91$; $p < 0.001$). Sensitization to Cupressaceae and Aspergillus had similar statistical result ($\chi^2 = 20$; $p = 0.001$ and $\chi^2 = 19.33$; $p = 0.001$). Sensitization to HDM was predominant in Beirut, North Lebanon, and Mount Lebanon but was low in the Beqaa region. On the other hand, sensitization to grasses, 4 cereals, and Cupressaceae was predominant in the Beqaa.

Regarding altitude, the data showed an inverse correlation between HDM sensitization and altitude where the number of sensitized patients decreased with increasing altitude (χ^2 = 68.84; $p < 0.001$). Sensitization to grasses and 4 cereals followed an opposite trend (G $\chi^2 = 14.86$; $p < 0.001$; Ce $\chi^2 = 16.98$; $p < 0.001$).

Among the 919 patients, four groups were identified: 167 (18.2%) with negative SPTs, 83 (9%) with one positive SPT, 448 (48.7%) with 2–4 positive antigen, and 221 (24%) with 5 or more positive SPT (polysensitized). The prevalence of positive skin prick test was 81.83% (95% CI 0.793–0.843).

The negative SPTs were found mainly in the 1–4 years group (40.5% vs 10.2% in 11–18 years) with a progressive decrease with age (Table 3).

Polysensitization showed an increasing trend with age ($\chi^2 = 93.46$; $p < 0.001$) (Fig. 3). However, the rate of polysensitized patients was similar in children younger and older than 10 years (31.8% vs 31.4%, respectively), showing a high number of polysensitized children younger than 10 years of age (Table 4).

The ANOVA test showed a significant relationship between age and polysensitization ($p < 0.001$). The post hoc analysis showed a significantly higher mean age (in years) of patients with 2–4 and ≥ 5 allergens compared with patients with negative SPT (8.65 vs 6.36: $p < 0.001$ and 9.03 vs 6.36: $p < 0.001$, respectively) and to patients who are monosensitized (8.65 vs 6.42: $p < 0.001$ and 9.03 vs 6.42: $p < 0.001$, respectively).

Among the 83 monosensitized patients, 13 (15.7%) were sensitive to Al, followed by 9 (10.8%) to DF and DP, 9 (10.8%) to Ce, 9 (10.8%) to D, 6 (7.2%) to O, 6 (7.2%) to GC, 5 (6%) to P, 5 (6%) to G, 4 (4.8%) to As, 4 (4.8%) to Pi, 3 (3.6%) to Cu, and 2 (2.4%) to C.

Sensitization rate to indoor allergens was consistently higher than to outdoor allergens among all age groups and both indoor and outdoor sensitization rates showed an

Table 2 Distribution of the allergens sensitization among the studied population according to the age groups

	% (number)			
	1–4 years ($N = 131$)	5–10 years ($N = 543$)	11–18 years ($N = 245$)	Total ($N = 919$)
Negative SPT	40.5% (53)	16.4%(89)	10.2% (25)	18.2% (167)
Positive SPT	59.5%(78)	83.6%(454)	89.8%(220)	81.8%(752)
D. pteronyssinus (DP)	30.8%(24)	57.1% (263)	70.5%(155)	59% (442)
D. farinae (DF)	37.2%(29)	54.2%(246)	70.5%(155)	57.2%(430)
5 grasses (G)	32.1% (25)	35.9% (163)	30%(66)	34% (254)
4 cereals (C)	15.4%(12)	37.6%(171)	31.8%(70)	33.6%(253)
Cat dander (C)	11.5% (9)	24.6%(134)	37.3%(82)	29.9%(225)
Alternaria (Al)	23.1%(18)	35%(159)	15%(33)	27.9%(210)
Parietaria (P)	12.8%(10)	17.7% (96)	30.5%(67)	23%(173)
Dog dander (D)	12.8% (10)	21.1% (134)	25.5%(56)	21.9%(165)
Olive (O)	12.8% (10)	18.5%(84)	27.3%(60)	20.5%(154)
Aspergillus (As)	15.4% (12)	19.8%(90)	17.3%(38)	18.6%(140)
Cupressaceae (Cu)	17.9%(14)	18.7%(85)	16.4%(36)	18%(135)
Pine (Pi)	12.8% (10)	22.7%(103)	6.8%(15)	17%(128)
German cockroach (GC)	19.2%(15)	15%(68)	7.7%(17)	13.3%(100)

increasing trend with age (I. $\chi^2 = 66.10$; $p < 0.001$; O. $\chi^2 = 22.85$; $p < 0.001$).

Sensitization to outdoor allergens was predominant in the Beqaa region ($\chi^2 = 24.97$; $p < 0.001$), whereas that to indoor allergens was more frequent in the other Lebanese regions except for Beirut ($\chi^2 = 25.83$; $p < 0.001$).

Bivariate analysis of factors associated with the presence vs absence of aeroallergens

A higher mean age (8.51 vs 6.36) was found in children with the presence of aeroallergens. Moreover, a significantly higher percentage of children who live at an altitude < 900 m (84.1% vs 75.0%) had aeroallergens (Table 4).

Multivariable analysis of factors associated with the presence vs absence of aeroallergens

The multivariable analyses results are summarized in Table 5. The results obtained were considered adjusted over gender and region since those two variables had a $p > 0.2$ in the bivariate analysis, thus, were not entered in the multivariable model.

The results of a first logistic regression, taking the presence vs absence of aeroallergens as the dependent variable and

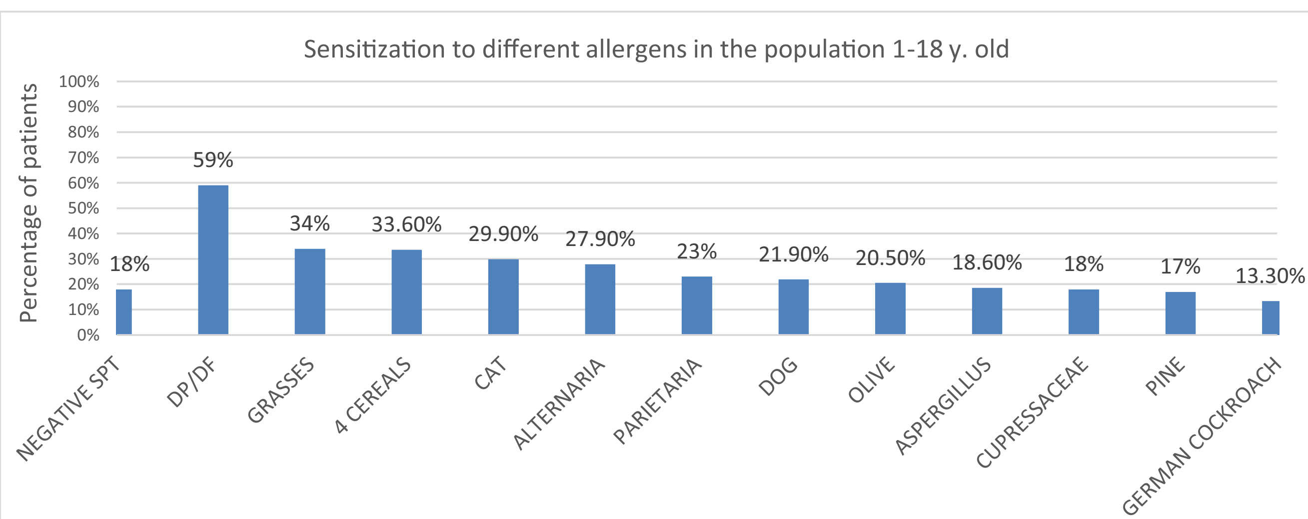
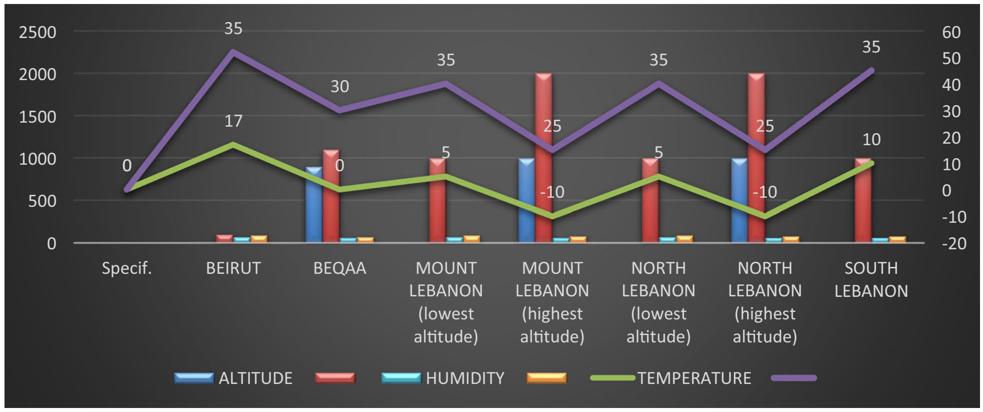


Fig. 1 Distribution of allergen sensitization among the whole population

Fig. 2 Description of the altitude, humidity, and temperature across the five regions in Lebanon



taking age as a continuous independent variable, showed that higher age (aOR = 1.24) and altitude less than 900 m compared with ≥ 900 m (aOR = 2.03) were significantly associated with the presence of aeroallergens in children (Table 5, model 1).

The results of a second logistic regression, taking the presence vs absence of aeroallergens as the dependent variable and taking age as a categorical independent variable, showed that altitude less than 900 m compared with ≥900 m (aOR = 1.90) and children aged 5–10 years (aOR = 3.51) and 11–18 years (aOR = 6.40) compared with the 1–4 years group were significantly associated with the presence of aeroallergens in children (Table 5, model 2).

Discussion

The main finding of this study is that the majority of children with atopic asthma had a positive SPT to a minimum of 2 allergens. Polysensitization was also frequent at young age. HDM were the predominant allergens, followed by 5 grasses, 4 cereals, cat, and Alternaria. Sensitization to indoor allergens was higher than to outdoor allergens, but both increased with age. According to geographical distribution, HDM sensitization was most frequent in all Lebanese areas, except in the inner region of the Beqaa, where grasses and 4 cereals allergens were predominant.

Atopy and multiple sensitizations

Epidemiologic data regarding the prevalence of atopic asthma in children are sometimes contradictory, probably because of environmental differences over the world. Our results, as those of Jurca et al. (2017), show that the asthma phenotypes pattern changes with age: non-atopic asthma is predominant in children but atopic asthma becomes more prevalent with age. Our results showed a higher prevalence of atopic asthma (positive SPT in 81.8% of cases), with the risk of having a positive SPT increasing with age. In our sample, atopic asthma was more common among children older than 5. These results are in agreement with the meta-analysis by Craig 2010) that showed a predominance of atopic asthma, as well as Ogershok et al. (Nielsen et al. 2017) who had atopic asthma in 50% of children older than 5 years and 70% of children older than 10 years.

Both atopy and multiple sensitizations (≥ 5 SPT) increase with age. By the age of 5, 24.9% of children are sensitized to 5 or more allergens. Our study suggests that the Lebanese children tend to develop polysensitization earlier, compared with other studies that have shown increasing prevalence of sensitization starting gradually at 7 years and peaking in puberty or early adulthood (Nielsen et al. 2017; Ogershok et al. 2007).

Early aeroallergen sensitization (before 8 years) and particularly polysensitizations were significantly associated with persistence of asthma into late childhood (Peat et al. 1990). This suggests that the Lebanese asthmatic children are more likely to have persistent asthma. However, this hypothesis needs to be tested by a prospective study.

Table 3 Rate of sensitization according to age group

Groups of age	Negative spt	1 positive allergen	2–4 positive allergens	5+ positive allergens
1–4 years	40.5%	18.3%	34.4%	6.9%
5–10 years	16.4%	9%	49.7%	24.9%
11–18 years	10.2%	4%	54.3%	31.4%
Total	18.2%	9%	48.7%	24%

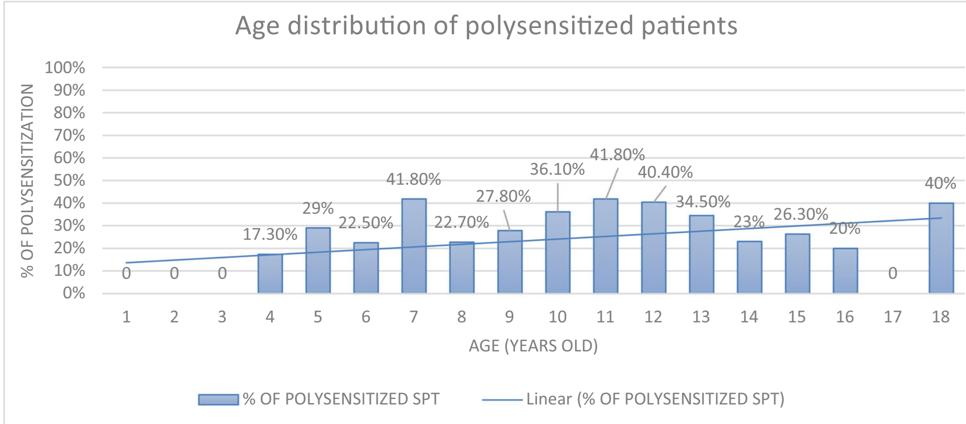


Fig. 3 Rate of polysensitization (positive SPTs to ≥ 5 allergens) according to age

Allergens

HDM, five grasses, four cereals, cat dander, and Alternaria were the five predominant aeroallergens causing positive SPT in our sample.

HDM was the most common allergen causing sensitization among all age groups (59%) with an increasing prevalence with age. The GA2LEN study showed high HDM sensitization in the Mediterranean countries such as Greece (32.7%) and Italy (38.9%) and in Southern Europe (Portugal 68.8%) (Heinzerling et al. 2009). The prevalence in our population was higher than in the other Mediterranean countries. The higher prevalence in the coastal humid regions compared with the drier Beqaa valley reflects the typical geographical distribution of mites Bessot and Pauli (2011).

The second most prevalent allergens were the five grasses (34%), with a rate similar to some European countries (Portugal 34.4%, Netherlands 35.5%, Greece 49.5%) (Heinzerling et al. 2009; Şahiner et al. 2012). Besides their geographic variation, pollens have a seasonal variation and require several exposures to induce sensitization (Verini et al. 2001), which explains the increasing sensitization with age. Our patients however appeared to develop sensitization to grasses in early childhood, as in the study by Ogershok et al. (2007) who showed pollen sensitization beginning as early as 2 years. A possible explanation could be the extended warm season in Lebanon, which increases the pollen concentration in the air. Sensitization to grass allergens was higher in the Beqaa where the pollen density was higher, as previously reported in the adult Lebanese population (Bazarbachi et al. 2014). Sensitization to cereals was also higher in the Beqaa

Table 4 Bivariate analysis of factors associated with the presence vs absence of aeroallergens in children

Variable	Absence of aeroallergens	Presence of aeroallergens	*p* value
Age (in years)	6.36 ± 3.44	8.51 ± 3.41	*< 0.001*
Age group			*< 0.001*
1–4 years	53 (40.5%)	78 (59.5%)	
5–10 years	89 (16.4%)	454 (83.6%)	
11–18 years	25 (10.2%)	220 (89.8%)	
Gender			0.474
Male	108 (17.5%)	508 (82.5%)	
Female	59 (19.5%)	244 (80.5%)	
Region			0.453
Beirut	18 (20.9%)	68 (79.1%)	
Bekaa	37 (21.8%)	133 (78.2%)	
Mount Lebanon	85 (17.6%)	398 (82.4%)	
South Lebanon	13 (18.1%)	59 (81.9%)	
North Lebanon	14 (13.3%)	91 (86.7%)	
Altitude			*0.002*
≥ 900 m	59 (25.0%)	177 (75.0%)	
< 900 m	108 (15.9%)	572 (84.1%)	

Table 5 Multivariable analyses

Variable	p value	aOR	95% confidence Interval	
Model 1: Logistic regression taking the presence vs absence of aeroallergens as the dependent variable and taking age as a continuous independent variable				
Age	< 0.001	1.24	1.17	1.31
Altitude (< 900 m vs ≥ 900 m*)	< 0.001	2.03	1.39	2.95
Model 2: Logistic regression taking the presence vs absence of aeroallergens as the dependent variable and taking age as a categorical independent variable				
Altitude (< 900 m vs ≥ 900 m*)	0.001	1.90	1.31	2.77
Age group				
1–4 years		1		
5–10 years	< 0.001	3.51	2.31	5.35
11–18 years	< 0.001	6.40	3.70	11.08

*Reference group

and in the 5–10 years age group. To be noted, grasses and cereals have high cross-reactivity (Damialis and Konstantinou 2011) and this could explain the similar rates of positive SPTs.

Cat allergen sensitization was higher than the general European rate (29.9% vs 23%) although in Lebanon, relatively few households keep cats at home. A possible explanation is the high number of feral cats in the community (Kelly et al. 2012).

Alternaria represented the fifth allergen by prevalence of sensitization. Its frequency appeared to be higher than in Europe, owing probably to the higher humidity. Alternaria was also the major allergen among the monosensitized children, followed by HDM and animal dander, making it one of the first allergens to induce sensitization. Since early exposure to molds (Alternaria, Aspergillus, and Penicillium) and to HDM has been associated with asthma in childhood and with increased exacerbations of asthma (Sheehan and Phipatanakul 2016), environmental interventions should aim at reducing this exposure in houses and schools.

Altitude

Geographic factors such as altitude affect the aeroallergen concentration and secondarily the sensitization pattern. Increasing altitude has been associated with lower HDM allergen concentrations (Grafetstatter et al. 2016, Vervloet et al. 1982). In our population, HDM sensitization was more frequent at lower altitudes (< 900 m). We also showed that the prevalence of sensitization to grasses and cereals was higher at higher altitude (≥ 900 m) than at sea level. The effect of altitude may however be confounded by other factors such as temperature, relative humidity, and air pollution level (Ozkaya et al. 2015). The climate in the Beqaa valley, characterized by its dryness because of its inland location, is probably also affected by its relatively high altitude.

Indoor and outdoor allergens

Sensitization to indoor allergens was more frequent than that to outdoor allergens in all age groups (74 vs 54.7%) and both increased with age. Indoor allergen sensitization seemed also to develop earlier. This difference becomes more significant when cereals are not included with the outdoor allergens, because of their cross-reactivity with other allergens, particularly grasses (Damialis and Konstantinou 2011). Our findings are in agreement with other studies that identified sensitization to indoor allergens in more than 80% of asthmatic children (Sheehan and Phipatanakul 2016). Because this sensitization is associated with persistence of asthma into later life (Ogershok et al. 2007), allergen avoidance through environmental control measures should be recommended for all high-risk children.

Limitations

Our study has some limitations. First, skin prick testing was not systematically performed on all asthmatic children and may have been selectively performed on patients with more severe disease. The results were not stratified according to disease severity and according to the presence or absence of other atopic conditions such as allergic rhinitis or eczema. Moreover, one prick test was done; no data is available whether there were any changes in allergens across the years. Second, the 21-aeroallergens panel used for testing was determined according to the known aeroallergen distribution in Lebanon. Some other aeroallergens may have become more prevalent in recent years and would have been missed.

Conclusion

This study shows a relatively high prevalence of the atopic phenotype in the Lebanese asthmatic children, with aeroallergens polysensitization beginning early in life. As showed by Jad Chaabana et al., Lebanon has a very high smoking rates for both cigarettes and waterpipes also at young age. More than a third of Lebanese adults are smokers and 78.9% of children in Lebanon are exposed to smoke (Chaaban et al. 2010). This, coupled with the high rate of smoking and the high level of pollution, makes these children at high risk of developing severe or persistent asthma (Salameh et al. 2015; Wang et al. 2016). If our findings are confirmed by further studies, the management of asthmatic children should include early testing for allergic sensitization (by 5 years). Patients with positive tests should receive in addition to medical therapy (corticosteroids, leukotriene receptor antagonists, antihistamines, etc.) instructions on allergen avoidance at home and at school and possibly allergen immunotherapy, which has been shown to prevent the acquisition of further allergies and the development of asthma (Ogershok et al. 2007).

Compliance with ethical standards The ethics committee at the Notre Dame des Secours University Hospital approved the study protocol.

Conflict of interest The authors declare that they have no conflict of interest.

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