

The impact of pollen load on quality of life: a questionnaire-based study in Lithuania

Ingrida Šaulienė · Laura Šukienė ·
Denis Kainov · Jūratė Greičiuvienė

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Abstract Populations worldwide have been increasingly affected by allergic rhinitis associated with pollen allergens. Alterations in the geographical distribution of pollinating flora resulting from climatic changes and increased production of pollens caused by higher atmospheric CO₂, have changed the environment in which humans reside. This study, carried out in Lithuania, aimed to demonstrate how people with pollen allergy are affected by symptoms associated with changing pollen loads and to evaluate the resultant changes in human quality of life. This study assessed pollen loads in Lithuania during 2013–2014. Skin prick tests were carried out on 665 individuals aiming to evaluate sensitivity to pollen allergens. Self-reports on symptoms and their impact on quality of life were collected from each study subject. There were 24× to 42× differences in inter-annual peaks of *Betula* pollen concentrations, while differences of plant pollen concentrations of the other genus/families varied from 1.5 to 92 % on peak days. Positive reactions to pollen allergens were reported in 54 % of the study subjects; 90 % of these subjects had been continuously suffering from moderate-to-severe

symptoms of allergic rhinitis. The most frequently reported symptoms were sneezing (99 %), runny nose (98 %) and stuffy nose (97 %). The dominant group of subjects reported symptoms during the entire period of vegetation (7 months). This study demonstrated that people with pollen allergies have attributed symptom-associated worsening of their quality of life to the typical periods of unavoidable exposure and have made only minimal changes in their lifestyle during the season of pollen load.

Keywords Pollen season · Aerobiology · Symptoms · Allergy · Rhinitis · Sensitisation

1 Introduction

The airborne pollen of anemophilous plants is one of the main causes of seasonal rhinitis and rhinitis-associated symptoms. Pollen concentration in the air is largely predetermined by emission from local plants (Estrella et al. 2006; Šikoparija et al. 2009). However, pollen concentrations in the air risky for the health of sensitive individuals were found under non-typical local circumstances (Sofiev et al. 2006; Siljamo et al. 2013). Local geographical conditions may result in different pollen concentrations of the same plant species in the atmospheres of different countries (Rodríguez et al. 2014); therefore, pollen load assessment in a specific territory is required from time to

I. Šaulienė (✉) · L. Šukienė · D. Kainov ·
J. Greičiuvienė
Department of Environmental Research and Physics,
Faculty of Technology and Natural Sciences, Šiauliai
University, Vilniaus Street 141, 78353 Šiauliai,
Lithuania
e-mail: ingrida.sauliene@su.lt

time for the analysis of pollen impact on quality of life. Studies have demonstrated that pollen concentration is increasing, especially in urban regions (Grewling et al. 2012; Ziello et al. 2012). Human respiratory systems in urban territories are affected not only by pollen, but also by the components of stationary and mobile air pollution of anthropogenic origin (Puc 2012b; Kanter et al. 2013). To maintain quality of life during everyday activities and to ensure timely prevention and diagnosis respiratory disease, it is important to be aware of the spread of pollen.

Identification of the airborne allergens most frequently causing sensitisation in humans is also of great importance for allergic rhinitis diagnosis and treatment (Moitra et al. 2014). Allergic rhinitis has negative impact on basic daily activities, resulting in declined social activity, reduced learning and work efficacy and impoverished leisure time (Bousquet et al. 2012). On the other hand, sensitivity to airborne allergens is a significant risk factor for asthma development, if sensitisation occurs in childhood (Raj et al. 2013). It was revealed that 16.2 % of people with allergic rhinitis in European populations have also suffered from asthma (Linneberg et al. 2002).

Pollen allergy has been associated with eye, nose and respiratory function disorders, expressed by different symptoms: eye redness, eye itching, watery eyes, stuffy nose, itchy nose, runny nose, sneezing and difficulty breathing (Bousquet et al. 2012). While assessing their own health status, people often fail to consider all circumstances, accepting symptoms caused by pollen as a normal condition, or often overestimating them (Lakhani et al. 2012). Epidemiological studies demonstrated that quality of life declines for people suffering from allergic rhinitis (Meltzer et al. 2012; Caillaud et al. 2015). Poor or late identification of symptoms leads to deterioration in quality of life and financial losses (Hellgren et al. 2010). Joint efforts of scientists, physicians and politicians have aimed to find solutions to improve the quality of life of people sensitive to the pollen of anemophilous plants. As the best prevention is the avoidance of contact with allergens, different environments have been created, allowing patients, physicians and allergists to be aware of pollen concentrations in specific territories. Research groups, acting on the basis of scientific initiative, or financially supported by a public funds, have been established in

many European countries and actively present information on pollen concentrations via their websites. These websites provide data varying from specific pollen concentrations to stylised summaries and evaluations. A free web-based tool, *Patient's Hay-fever Diary* (www.pollendiary.com), has helped over 25,000 users to self-assess the effects of pollen on their allergy-related symptoms (Berger et al. 2013). Knowledge of pollen load and principles of symptom prevalence, and their impact on the quality of life, is important for improvement in current opportunities as well as for development of tools in the future.

The aim of this 2-year study, carried out in Lithuania, was to demonstrate how people with allergies to pollen are affected by their symptoms and how the symptoms are associated with pollen load, and to evaluate changes in lifestyle as well as quality of life.

2 Materials and methods

2.1 Aerobiological data

Airborne pollen were collected during the period 2013–2014 in the three biggest cities of Lithuania: Vilnius (54°45'N, 25°16'E), Klaipėda (55°45'N, 21°07'E) and Šiauliai (55°55'N, 23°18'E). Hirst-type volumetric pollen traps (Hirst 1952) were installed 18–20 m above the ground surface. Pollen analysis in a sample applied the standard counting method, with twelve vertical sweeps of the slides (Galán et al. 2014). Pollen load in this study was characterised by pollen most often found in air samples, namely, pollen of *Alnus*, *Artemisia*, *Betula*, *Carpinus*, *Corylus*, *Cupressaceae*, *Fraxinus*, *Poaceae*, *Quercus* and *Salix*. Pollen load was expressed in pollen concentration during 24-h periods (pollen grains/m³). Pollen season was established applying the 95 % method (Emberlin et al. 1997).

2.2 Subject data

2.2.1 Skin prick tests

Adults (>18 years old), who visited outpatient doctor-allergist clinics and agreed to participate in the study, were enrolled, and the study was carried out during the period 2013–2014.

Skin prick tests for all volunteers were performed with AlyostalPrick allergen extraction solutions to assess the allergen sensitivity of the study subjects. Each subject was tested for the allergens most frequently used in Lithuania: *Betulaceae* (*Alnus*, *Corylus*, *Betula*, *Carpinus*) and *Poaceae* (*Dactylis glomerata*, *Anthoxanthum odoratum*, *Lolium perenne*, *Poa trivialis*, *Phleum pratense*) mixtures and *Artemisia vulgaris*, *Helianthus annuus*, *Alternaria*, *Cladosporium*, as well as cat and dog hairs, and mite allergens. Data of persons allergic to the allergens of *Artemisia vulgaris* and *Helianthus annuus* were analysed in the study by merging them into the *Asteraceae* group. Phenolated glycerol–saline was used as a negative control, and histamine solution was used as a positive control. The results were assessed on average after 20 min from the beginning of test (Heinzerling et al. 2013). Sensitivity was established by comparing blister reactions to the studied allergen sample and a control sample. A test result was considered positive if the diameter of the wheal was bigger than 3 mm. Positive reactions to a negative control were not reported by any study subjects, and all study subjects demonstrated positive reactions to histamine.

Only the data of subjects with the positive reactions to pollen allergens were involved in the analysis described in this article.

2.2.2 Questionnaire

A questionnaire was developed covering general personal information and allergy trigger-related indicators of quality of life. The main foci were the time of onset of symptoms, their duration and the impact of health disorders on outdoor activities. The questionnaire had to be completed by the study subjects themselves. They had to indicate symptoms, such as tiredness/lack of energy, and the impact of these symptoms on daily activities. The conclusions regarding severity of allergic rhinitis were made according to the *Guide on Allergic Rhinitis and its Impact on Asthma* (ARIA) (Bousquet et al. 2008). The impact of the symptoms on quality of life was identified by analysing the weekly duration of effects, using the following criteria: every day, more than 2 days, <2 days and never.

To assess the intensiveness of staying outdoors, the study subjects were asked to define the time they spend

outdoors by three categories. The first category covered individuals who tend to stay outdoors for a short time (<2 h); the second group consisted of people staying outdoors an average of 2–6 h per 24 h; and the third category included people who usually spend >6 h being outdoors. Such stratification enabled evaluating whether persons experiencing hay fever symptoms knowingly limit their outdoor activities in order to avoid contact with allergens.

2.2.3 Ethical considerations

The permission to conduct this study was issued by the Lithuanian Bioethics Committee (No. 158200-13-633-200). The study subjects voluntarily consenting to participate in the study were informed about the study objectives and processes. The study subjects were informed that they can leave the study at any time, and confidentiality of their data will be maintained in any case. The study subjects have signed the documents of Subject's Information and Informed Consent to participate in the study. Skin prick test was performed by a professional medical staff.

2.3 Data analysis

Data analysis and visualisation were performed using the software STATISTICA. The software Venn diagram plotter (Pacific Northwest National Laboratory, <http://omics.pnl.gov/software/venn-diagram-plotter>) was used for grouping of study subjects' data.

Based on the reaction to allergens established by a skin prick test, the study subjects were allocated into the groups: subjects sensitive to pollen only, and those with additional sensitisation to at least one other allergen (*Alternaria*, *Cladosporium*, hair of cats or dogs).

A pollen season was defined during the assessment of pollen levels in the air, the dates of the season's beginning and end were identified, and mean and maximal diurnal concentrations of pollen were established. Standard deviation was calculated, aiming to assess the seasonal dynamics of concentration. Comparison of average concentration of pollen between the years and locations was made, applying *t* test for independent groups. The rate of personal reports in percentile was calculated, aiming to identify the duration of symptoms causing deteriorating quality of life. Frequency of qualitative characteristics

between study groups was compared using the Chi-square criterion. The Box–Whisker method was used to evaluate differences in concentrations among the regions involved in the analysis, aiming to establish dispersion of the study subjects by the groups of age and sensitisation to allergens. A case was considered as statistically significant, if $p < 0.01$, $p < 0.05$.

3 Results

3.1 Review of study sample and allergic sensitivity

The study was carried out during the period 2013–2014 and involved 665 study subjects. All of the subjects were tested with the same skin prick tests for sensitivity to pollen, fungi spores and animal allergens. The results of the tests demonstrated that 54 % of study subjects were sensitive to pollen allergens (Fig. 1).

Analysis of data of the study subjects with regard to pollen sensitivity revealed that the dominant portion of study subjects (24 %) had positive reactions to the allergens of *Asteraceae* plants (Fig. 1); however, they were not sensitive to other pollen allergens tested. 8.6 % of study subjects were sensitive to the allergens contained in the spores, and 58 % were sensitive to the allergens of cat or dog hair and/or mite allergens. Positive reaction to pollen antigens, accompanied with sensitivity to mould and animal antigens, was found in

242 study subjects in total. 118 subjects enrolled in the study (59 % males and 44 % females) were sensitive to pollen antigens only. More than two-thirds (70.3 %) of the study subjects were living in a city.

Seven groups were formed according to the results of the reaction to pollen antigens (Fig. 2): sensitive to *Asteraceae* only; to *Betulaceae* only; or to *Poaceae* only, and sensitive to the allergens of several plant families—*Asteraceae–Poaceae*; *Betulaceae–Poaceae*; *Asteraceae–Betulaceae*; *Asteraceae–Betulaceae–Poaceae* (Fig. 3—“All 3 types”).

The average age in the study groups was 37–47 years (Fig. 2). The eldest person with sensitivity to pollen allergens was 77 years old (positive reaction to *Asteraceae* allergens). Individuals sensitive to *Poaceae* allergens were the youngest (age median was 30, SD = 15.8) in comparison with other groups. The smallest age distribution among the study subjects was in the *Betulaceae–Poaceae* group (SD = 6.2). The assessment of distribution of allergen-sensitive individuals ($\chi^2 = 4.92$ $p = 0.03$), according to place of residence, revealed that the residents of urbanised areas were more often sensitive to the pollen allergens both of a single plant family (68.2 %) and of their mixtures (72.5 %).

Information on the effects of pollen for the study subjects obtained from questionnaires was summarised, and the impact of allergens on the well-being of the study subjects and their quality of life were assessed. Subjects allergic to pollen 90 % ($n = 360$) have been continuously suffering from moderate-to-severe allergic rhinitis symptoms among all subjects.

3.2 Assessment of pollen seasons

For the assessment of the airborne pollen season in the aspect of allergic rhinitis/hay fever, the most important indicators allowing identification of the effects on health are: duration of the factor (pollen), activity (a period of detection in the air), and intensiveness (concentration). Characteristics of certain pollen seasons (during the period of the study) are presented in Tables 1 and 2.

Differences in season characteristics were observed, both in terms of territory and time. In 2014, the pollen season was longer in 70 % of cases, compared with 2013. The beginning of the season was delayed in recent years, but not in 2014, with the exception for *Artemisia* in Šiauliai and Vilnius.

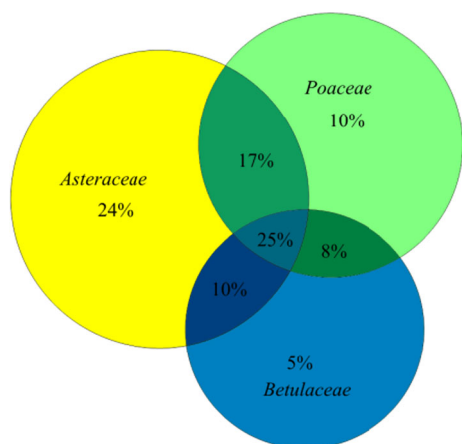
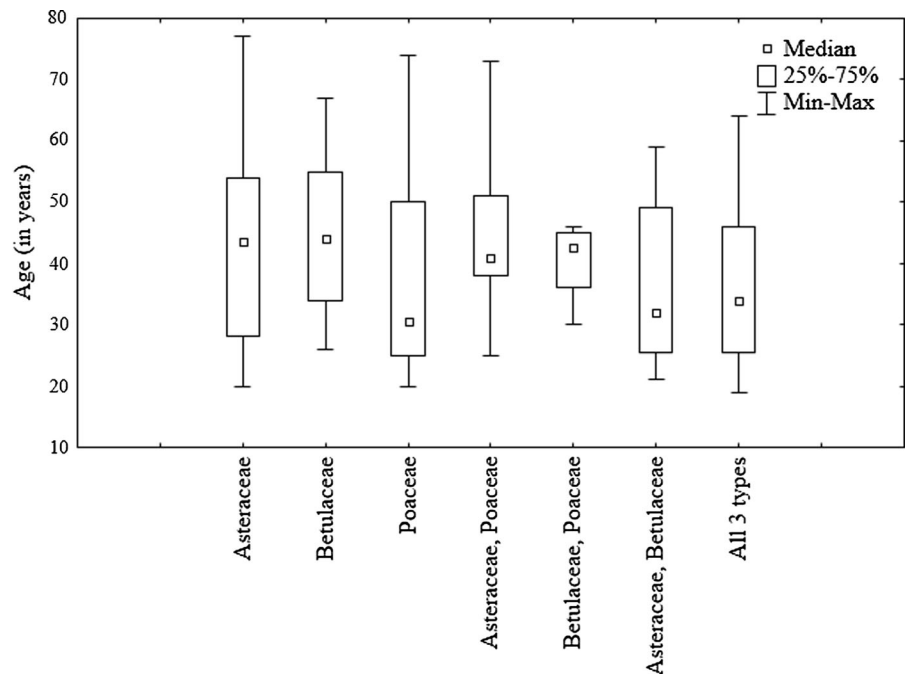


Fig. 1 Distribution of pollen sensitive study subjects ($n = 360$) according to positive reactions to allergens

Fig. 2 Age of study subjects ($n = 118$) according to positive reaction to pollen allergens



Despite the fact that differences in the beginning and end of the pollen season were up to 48 days in 2013–2014, the mean difference between the beginning (12.11, SD = 16.83) and end (15.81, SD = 20.93) of season was insignificant.

Among the entire spectrum of pollen analysed in 2013, *Alnus* was characterised by high mean and peak concentrations. The highest diurnal concentration of pollen was recorded on 16 April, irrespective of the location of sample collection. The highest concentrations in 2014 were reported for the plants of the *Betula* genus, and the day of peak was recorded almost at the same time (20–21 April). The most significant difference in pollen concentrations for individual year was calculated for *Betula* and *Quercus* in all study locations. The amount of *Carpinus*, *Cupressaceae* and *Salix* pollens found in the samples was low in both study years, and differences in concentrations for individual years were often insignificant.

Diurnal concentration of *Betula* pollen in Šiauliai was significantly lower than in Vilnius and Klaipėda (Fig. 3). In the case of *Fraxinus*, the mean indicator was significantly higher in Vilnius, compared with Klaipėda and Šiauliai. Analysis of *Corylus* pollen dispersion in Lithuania revealed differences among all three stations. The significant differences in mean

grass pollen concentration among the stations were reported in 2014 only. Differences for *Artemisia* were found between the pollen concentrations recorded in the aerobiological stations at the seacoast, and in the continental part, mean diurnal concentration of *Poaceae* pollen was significantly higher in Vilnius.

3.3 Self-reported symptoms and pollen load

Study subjects identified their symptoms of tiredness in the self-reports. The following frequency of symptoms was calculated based on the summarised data: dyspnoea (62 %), watery eyes (73 %), eye redness (86 %), itching eye (86 %), difficulty breathing (91 %), nose itching (95 %), stuffy nose (97 %), running nose (98 %) and sneezing (99 %). All study subjects with positive reaction to *Betulaceae*–*Poaceae* allergens indicated that they suffer from all above-mentioned symptoms. Individually, study subjects sensitive to *Betulaceae* or *Poaceae* allergens only experienced less symptoms, compared with the other study groups.

Our analysis on the intensiveness of different symptoms experienced by individuals sensitive to pollen allergens (7 groups, Fig. 2) revealed that 62–100 % of study subjects daily (during the

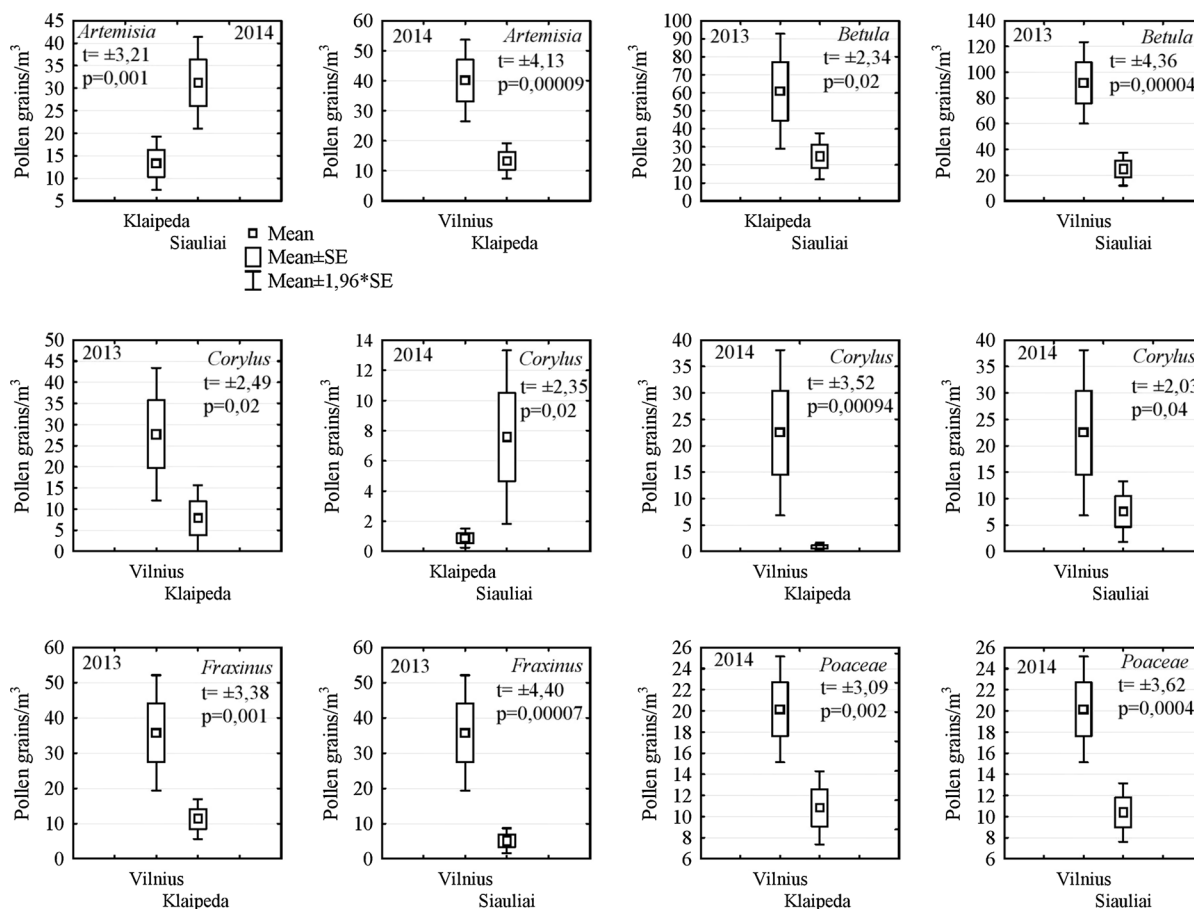


Fig. 3 Comparison of diurnal mean value of pollen concentrations in different cities. Only statistically significant differences are presented

symptomatic period) suffered from running nose; a smaller, but still significant (46–83 %), group of study subjects experienced sneezing and itchy nose. Self-reports on pollen effects on individuals exceptionally sensitive to *Betulaceae* allergens demonstrated that these individuals suffer from the above-mentioned symptoms less often, compared with the study subjects from other groups. Study subjects experiencing symptoms noted, wheezing or chest tightness as symptoms only very rarely. Study subjects reported that they suffered from dyspnoea not more than 2 days per week; mono-sensitised individuals experienced this disturbance less often, compared with poly-sensitive ones. Based on the self-reports of study subjects, we found 57–67 % of study subjects from different sensitivity groups experienced sleep disturbances more than 2 days per week, except those with

sensitivity to *Betulaceae* allergens. Fifty-four per cent of these latter study subjects reported that pollen load had no impact on their sleep quality. More than half of the study subjects evaluating pollen effect on their everyday activities noted that they did not experience any tiredness.

Figure 4 represents the combination of pollen load data (area chart) and study subjects' self-reportage of the deterioration of health outcomes (prevalence of symptoms percentage in timescale). Pollen load charts illustrate the 2-year airborne pollen season dynamics of Lithuania. Our research shows that people declare allergic rhinitis symptoms all year-round, but for a majority of subjects health greatly deteriorates during pollen season. 80 % of individuals suffered from the symptoms in May, during the blooming period of the majority of trees. Despite the fact that individuals

Table 1 Start, end and duration of pollen season in Lithuania during 2013–2014

Pollen type	Pollen season					
	Start		End		Duration	
	2013	2014	2013	2014	2013	2014
Vilnius						
<i>Alnus</i>	04.12	03.08	04.25	03.29	13	21
<i>Artemisia</i>	07.19	07.21	08.18	08.21	30	31
<i>Betula</i>	04.12	04.09	05.13	05.01	31	22
<i>Carpinus</i>	04.27	03.22	05.12	05.10	15	49
<i>Corylus</i>	04.12	03.08	04.26	03.26	14	18
<i>Cupressaceae</i>	04.16	03.13	06.25	06.09	70	88
<i>Fraxinus</i>	04.26	04.15	05.12	04.29	16	14
<i>Poaceae</i>	05.30	05.24	08.25	08.03	87	71
<i>Quercus</i>	05.06	04.26	05.22	05.24	16	28
<i>Salix</i>	04.19	03.23	05.15	04.24	26	32
Klaipėda						
<i>Alnus</i>	04.10	03.05	05.12	03.30	32	25
<i>Artemisia</i>	07.27	07.05	08.17	08.30	21	56
<i>Betula</i>	04.12	04.18	05.15	05.01	33	13
<i>Carpinus</i>	05.02	04.07	05.23	05.20	21	43
<i>Corylus</i>	04.12	03.07	05.12	04.07	30	31
<i>Cupressaceae</i>	04.16	03.21	07.08	07.06	83	107
<i>Fraxinus</i>	04.18	04.18	05.20	04.29	32	11
<i>Poaceae</i>	05.29	05.22	08.23	08.23	86	93
<i>Quercus</i>	05.09	05.07	05.23	06.18	14	42
<i>Salix</i>	04.22	03.21	05.30	04.24	38	34
Šiauliai						
<i>Alnus</i>	04.12	02.24	04.23	03.29	11	33
<i>Artemisia</i>	07.21	07.21	08.18	08.22	28	32
<i>Betula</i>	04.16	04.12	06.03	05.06	48	24
<i>Carpinus</i>	05.07	03.21	06.03	05.22	27	62
<i>Corylus</i>	04.12	02.23	04.28	03.25	16	30
<i>Cupressaceae</i>	04.17	03.15	06.23	06.17	67	94
<i>Fraxinus</i>	04.26	04.19	05.22	05.01	26	12
<i>Poaceae</i>	05.27	05.24	09.05	09.13	101	112
<i>Quercus</i>	05.15	04.29	05.27	05.22	12	23
<i>Salix</i>	04.19	03.21	05.27	05.07	38	47

sensitive to pollen of *Asteraceae* plants, blooming in the second half of summer, were predominant (76 %) in the study group (Fig. 4), the hay fever symptoms occurred in less than 68 % of study subjects during pollination period. The results of the survey demonstrated that 20–40 % of study subjects had suffered from these symptoms also in winter.

Analysis of the results of study subjects' well-being according to the groups of pollen sensitisation (Table 3) revealed that condition of the majority of study subjects (1–5 positions) worsened in the months when the plants, sensitising these individuals, were blooming. Study subjects sensitive to three allergens (*Asteraceae–Betulaceae–Poaceae*) indicated that they experienced allergic rhinitis symptoms deteriorating their quality of life most often in May. Table 3 illustrates that study subjects most often (73.8 % of cases) stayed in an outdoor environment 2–6 h both during working days and over weekends. However, some (31.9 % of cases) sensitive individuals tended towards limiting their time spent outdoors. Analysis of self-reports demonstrated that individuals sensitive to *Poaceae* allergens did not spend more than 6 h outdoors, irrespective of the day of week. Unlike the other groups, half of the study subjects sensitive to *Betulaceae–Poaceae* allergens indicated that they spend up to 6 h outdoors in spring. Mono-sensitised individuals have identified more uniform (>60 % of cases) behaviour related to the duration of staying outdoors, compared with polysensitised study subjects. Shorter time spent outdoors in spring compared with autumn is a regularity, and this tendency has low dependence on the pollen group sensitivity of individual.

4 Discussion

Impact of pollen on the quality of life is associated with both pollen load in a territory (Fereidouni et al. 2010; Velasco-Jiménez et al. 2014) and lifestyle (Kiotseridis et al. 2013; Lâm et al. 2014). Lithuania belongs to the group of countries in which pollen of *Betulaceae*, *Poaceae* and *Asteraceae* family plants are predominantly reported among allergenic pollen in air samples (Yli-Panula et al. 2009; Jantunen et al. 2012; Sauliène and Veriankaite 2012; Šauliène et al. 2014). It was demonstrated in the study carried out during 2013–2014 that pollen concentrations in adjacent years can be significantly different, and prevention of diseases associated with airborne pollen becomes more difficult due to this factor. For instance, mean diurnal pollen load of *Betula* was below 100 pollen grains/m³ in 2013 and exceeded 2000 pollen grains/m³ in 2014. There were 24–42 times differences in inter-annual peak of *Betula* pollen concentration in the

studied years, while differences of plant pollen concentration of the other genus/families varied from 1.5 to 92 % at the days of peaks (Table 2). These tendencies were detected irrespective of study sample collection in the territories located at the different distances from the sea: aerobiological traps were installed in the city at the seacoast (3-km distance for the sea) and at the centres in difference distances 148 and 281 km towards to the continental part. Similar inter-annual variations of *Betula* pollen concentrations

Fig. 4 Comparison of the periods when study subjects ($n = 360$) suffer from deteriorated quality of life with pollen load. Prevalence of declared symptoms by the study subjects is presented in percentile

were reported by the scientists from other countries (Yli-Panula et al. 2009; Puc 2012a). There have been attempts to describe the causality of such inter-annual differences; however, a unanimous answer has not yet been found. It has been noted in long-term pollen research that pollen variations were predetermined by

Table 2 Dynamics of pollen concentration (pollen grains/m³) during the period 2013–2014

Pollen type	Mean		Peak		SD ^a		<i>t</i> ^b	<i>p</i> [*]
	2013	2014	2013	2014	2013	2014		
Vilnius								
<i>Alnus</i>	161	210	503	1163	159	314	−1.58	0.11
<i>Artemisia</i>	46	40	197	123	47	37	0.50	0.62
<i>Betula</i>	92	2000	348	8503	91	2489	− 4.35	0.00
<i>Carpinus</i>	5	1	22	12	6	2	4.36	0.00
<i>Corylus</i>	28	22	108	110	31	35	0.46	0.65
<i>Cupressaceae</i>	2	2	17	19	4	3	1.19	0.24
<i>Fraxinus</i>	36	29	123	91	34	31	0.56	0.58
<i>Poaceae</i>	16	20	98	107	20	22	−1.17	0.24
<i>Quercus</i>	23	1	59	9	19	2	6.13	0.00
<i>Salix</i>	14	11	53	29	14	8	1.04	0.30
Klaipėda								
<i>Alnus</i>	150	105	1437	628	338	158	0.90	0.37
<i>Artemisia</i>	41	13	257	102	67	22	2.73	0.01
<i>Betula</i>	61	2843	318	7612	92	2726	− 5.85	0.00
<i>Carpinus</i>	3	1	16	6	4	1	2.92	0.01
<i>Corylus</i>	8	1	101	8	22	2	1.82	0.07
<i>Cupressaceae</i>	2	1	13	17	3	3	1.24	0.22
<i>Fraxinus</i>	11	29	73	74	16	21	− 2.99	0.01
<i>Poaceae</i>	13	11	108	98	19	17	0.73	0.47
<i>Quercus</i>	25	1	175	7	45	1	3.58	0.00
<i>Salix</i>	7	3	47	15	10	4	2.17	0.03
Šiauliai								
<i>Alnus</i>	210	140	812	663	255	182	−1.16	0.25
<i>Artemisia</i>	34	31	98	136	31	30	0.37	0.72
<i>Betula</i>	25	1791	204	8510	46	2584	− 4.82	0.00
<i>Carpinus</i>	0	0	6	2	1	0	1.97	0.05
<i>Corylus</i>	21	8	144	72	39	16	1.71	0.09
<i>Cupressaceae</i>	2	1	19	11	4	2	2.23	0.03
<i>Fraxinus</i>	5	34	40	78	9	21	− 6.06	0.00
<i>Poaceae</i>	14	10	86	74	18	15	1.47	0.14
<i>Quercus</i>	15	1	39	6	14	1	4.99	0.00
<i>Salix</i>	8	5	29	22	8	6	1.53	0.13

* Statistically significant values are emphasised in bold

^a SD of pollen concentration during the season

^b *t* test value of pollen concentration means during a season between 2013 and 2014

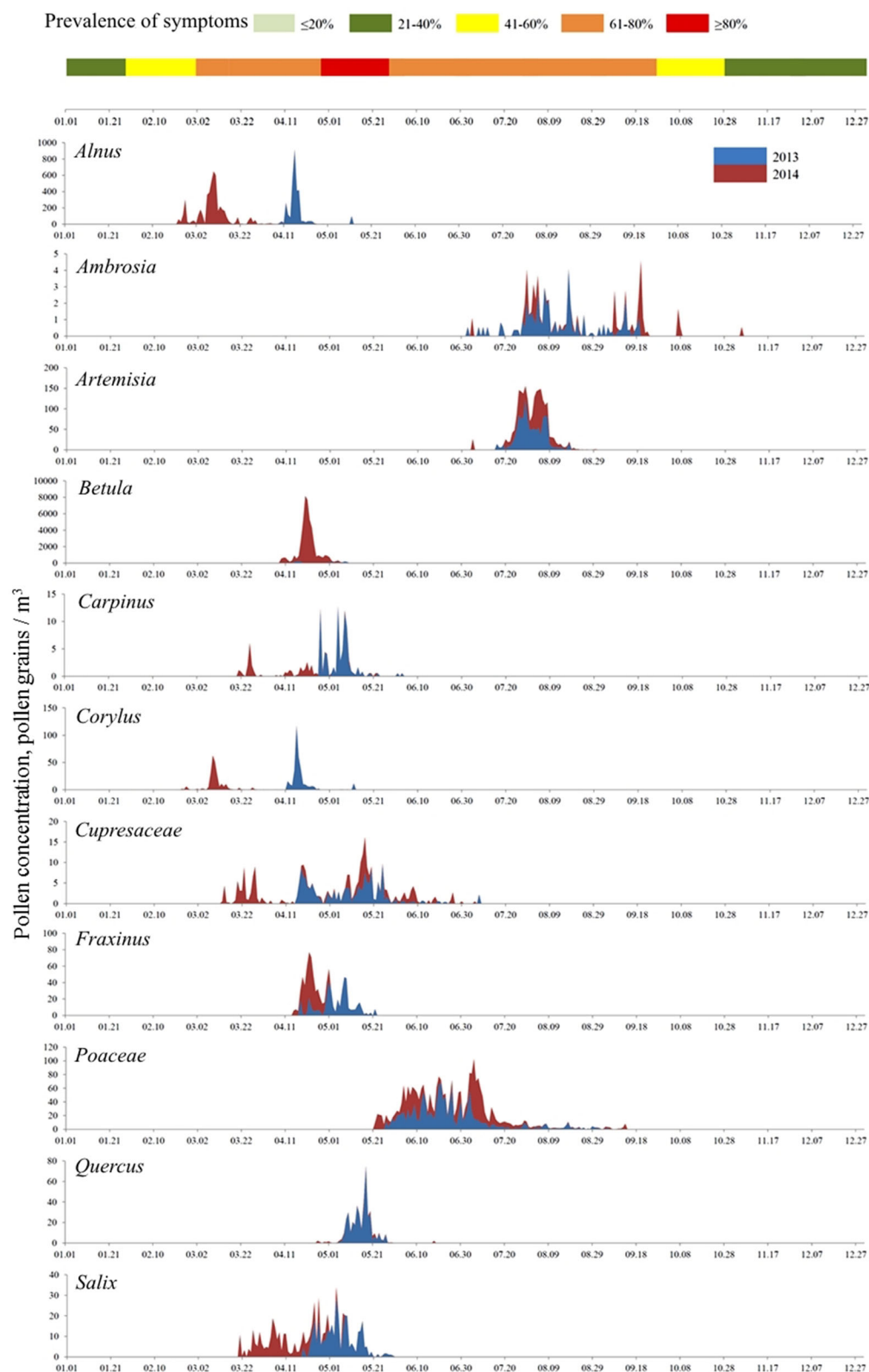


Table 3 Intensiveness of the outdoor activities of study subjects (according to allergen sensitivity groups), based on data of personal reporting

Eil. nr.	Allergen groups	Month (%)	Working days, h (%)			Weekends, h (%)		
			Spring	Summer	Autumn	Spring	Summer	Autumn
1.	Asteraceae	August (82)	<2 (56)	2–6 (59)	2–6 (74)	<2 (41)	2–6 (64)	2–6 (74)
2.	Betulaceae	April (92)	<2 (85)	2–6 (77)	2–6 (85)	2–6 (62)	2–6 (77)	2–6 (77)
3.	Poaceae	May (79)	<2 (64)	2–6 (64)	2–6 (64)	<2 (50)	2–6 (71)	2–6 (79)
4.	Asteraceae–Poaceae	May (94)	<2 (82)	<2 (41)	2–6 (53)	<2 (59)	2–6 (65)	2–6 (59)
				2–6 (41)				
5.	Betulaceae–Poaceae	April (100)	2–6 (50)	<2 (33)	<2 (33)	2–6 (50)	2–6 (50)	2–6 (50)
		May (100)		2–6 (33)	2–6 (33)			
				>6 (33)	>6 (33)			
6.	Asteraceae–Betulaceae	March (83)	<2 (67)	2–6 (67)	2–6 (75)	2–6 (75)	2–6 (67)	2–6 (75)
7.	Asteraceae–Betulaceae–Poaceae	May (88)	<2 (81)	2–6 (50)	2–6 (50)	<2 (50)	2–6 (63)	2–6 (69)

Third column indicates a month when worsened quality of life was reported in the biggest group of study subjects

changes in climate conditions (Yli-Panula et al. 2009; Ziello et al. 2012), by location of aerobiology stations in the urban/rural territories (Bosch-Cano et al. 2011; Cariñanos and Casares-Porcel 2011) as well as by differences arising from geographical latitude. In our case, meteorological conditions had a certain influence on the air levels of pollen of spring blooming plants. The beginning of the pollen season of early spring phenoidicators *Corylus* and *Alnus* in 2013 coincided with the beginning of the pollen season of *Betula*; however, there was a gap of approximately 46 days between the beginning of *Corylus/Alnus* and *Betula* pollen seasons in 2014. Such circumstances make it difficult to apply preventive measures for individuals sensitive to pollen allergens. On the other hand, higher productivity of some plants in 2014 following low emissions of their pollen in 2013 should be considered as a regular phenomenon from the physiological point of view.

Sufficient density of aerobiological monitoring networks ensures reliable results and, at the same time, serves as an important element for prognosis during the preparation of public information on the airborne pollen load. The network for aerobiological sample collection in Lithuania enables scientists to precisely assess the impact of territorial factors. This study revealed significant differences in *Corylus*, *Betula*, *Fraxinus*, *Poaceae* and *Artemisia* pollen concentrations, occurring due to geographical influence. The earliest blooming *Corylus* in Lithuania is spread sporadically and has constituted about 1 % of

forest stand (Food and Agriculture Organization of the United Nations 2010). This can be one of the crucial reasons predetermining significant differences in *Corylus* pollen concentrations among the study locations. *Poaceae* pollen levels are associated with the planting peculiarities of urban regions (Velasco-Jiménez et al. 2014), and Vilnius is distinguished from other study locations by large green areas with lots of meadow grasses. It has been demonstrated on numerous occasions that vegetative coverage was a direct influence on the pollen load (Skjøth et al. 2014; Thibaudon et al. 2014). The green areas constituted about 20–25 % of the territory at the study locations; nevertheless, pollen levels reported in these locations were significantly different. For instance, *Poaceae* pollen concentration in Vilnius was higher, when compared with Šiauliai and Klaipėda. Causes of such phenomena could be the influence of city microclimates on pollen emissions. For example, pollen levels in Vilnius are higher due to increased temperature in the city, predetermined by intensive urbanisation. Increased production of *Poaceae* pollen can be a result of elevated CO₂ levels, as compared with other study locations. Such influence on the production of *Artemisia* pollen was disclosed by Ziska and Caulfield (2000). In our case, prevalence of *Artemisia* plants was restricted by the biotype of the seacoast zone; therefore, pollen concentration is higher in the continental zones.

It was established that elevating air temperature results in changes of specific pollen emissions (Ziello

et al. 2012)—both in pollen levels in the air and in the duration of the pollen season. The pollen emission period was longer in 2014, compared with 2013, due to earlier start of the local vegetation season. The first positive samples of alder pollen in 2014 were reported at the end of February and could be associated with the long-distance dispersal of bioparticles in the air mass (Sofiev et al. 2006; Siljamo et al. 2013). The end of the season was reported as delayed by a few days in many cases, however, less significantly when compared with the beginning of the season. That duration of the pollen season in certain cases may differ by up to three times (such as for a hornbeam or an oak in Vilnius, or an alder in Šiauliai) has demonstrated that neither allergists nor their patients, as well as people sensitive to pollen allergens, can feel safe while following only general phenology calendars for prevention of the effects of environmental factors.

This assumption has been confirmed by our study involving individuals sensitive to pollen allergens. The study revealed that 54 % of the subjects enrolled in the study were polysensitised, i.e. they were sensitive both to pollen as well as spores and/or animal allergens. Sensitivity to pollen only was diagnosed for 18 % of study subjects, and 56 % of the study participants developed positive reaction to the allergens of plants belonging to one family. Authors of similar studies (Dondi et al. 2013; Moitra et al. 2014) have noted that there are less monosensitised individuals, compared with those demonstrating positive reactions to the allergens of several pollens, or having allergies to other environmental factors. Our studies are challenging due to the effect of pollen on the quality of life being analysed in groups of adults involving individuals up to 77 years old. The average age of the participants was that of employable people, thus proper assessment of pollen impact on their health was important. We have demonstrated that the characteristics of some pollen seasons of adjacent years were significantly different; based on self-reports of the study subjects, we found that individuals tended to follow stereotypic knowledge or approaches for the effect identification. Despite the low intensity of the pollen season in 2013, it was identified by the study subjects as the most often associated with symptoms, similar to the assessments of 2014. A small portion of study subjects indicated that they experienced symptoms all year around, while the dominant group included individuals who declared symptoms during the entire period of vegetation

(7 months). Symptom-associated studies demonstrated that, in the majority of cases, duration of symptoms was up to 3 months (Song and Park 2013), or several peaks of symptoms were reported lasting up to 2 months (Yamauchi et al. 2009). Poorly identified periods of symptoms make it difficult to apply preventive measures or to control the course of disease. Prolonged symptoms are inevitable phenomena, as mono-sensitised individuals constitute only a small part of the population. Moreover, subjects in our study experienced several symptoms. Symptoms of four types were associated with nose dysfunction, and subjects reported these symptoms most often (95–98 %). Watery eyes, eye redness and eye itching were indicated as quality of life-worsening factors in 73–86 % of cases in this group. It was demonstrated in our study that individuals exclusively sensitive to the allergens of *Betulaeae* or *Poaceae* reported less symptoms, compared with individuals from other study groups. Different intensities of symptoms were revealed in the study of allergic rhinitis effects on the populations of children and adults (Meltzer 2001). Frequency of symptoms was assessed in the analysis of pollen impact on quality of life. Despite the fact that sneezing as a symptom was indicated by the majority of study subjects, this symptom was less often indicated in the questionnaires, compared with runny nose. Long-term prevalence of this symptom may lead to the development of more severe forms of rhinosinusitis (Meltzer et al. 2004). The results of an 18-year-long study showed that dyspnoea and chest wheezing in the Swedish population are becoming more frequent and severe (Bjerg et al. 2011), which undoubtedly has a negative impact on the quality of life. Our study subjects reported that they suffered from dyspnoea and chest tightness not more than twice per week. Sleep disturbances, potentially occurring due to pollen sensitisation, were reported with the same rate. Despite the fact that study subjects reported many symptoms, at the same time, they indicated that these do not interfere significantly with their everyday activities and almost do not disturb their sleep; however, nearly all of them noted absence of hay fever symptoms. We thus may assume that the addressed health disorders are often considered normal conditions due to the effects of permanently experienced symptoms.

The assessment of pollen load and its correlation with individual sensitivity to pollen allergens has revealed that high diurnal levels of pollen do not necessarily correlate with progressive individual

sensitivity to allergens. For example, we found the biggest pollen load during the period 2013–2014 was produced by birch trees, which reached up to 8000 m³ of pollen in 24-h. Only 5 % of study subjects sensitive to pollen were sensitive exclusively to the allergens of the *Betulaceae* family; however, a much larger percentage of individuals sensitive to the birch family were sensitive to other plant antigens tested, though their diurnal concentration in the air does not exceed several hundreds of pollen particles in m³. On the other hand, it should be noted that pollen of this type are identified as the main airborne allergens of biological origin in the countries of Northern Europe (Yli-Panula et al. 2009; Grewling et al. 2012; Šauliune et al. 2014). Considering the results of pollen sensitivity tests, this suggests that the Lithuanian population is immune to pollen allergens of such type.

Studies of pollen load and atypical human reactions leading to the development of hay fever symptoms have repeatedly proven the influence of allergenic pollen concentration on a course of allergic disease. Researchers demonstrated that hay fever symptoms have negative impact on quality of life (Linneberg et al. 2002; Kiotseridis et al. 2013). On the other hand, the relations of pollen and people have been predetermined by different socio-economical and geographical factors (Yamauchi et al. 2009; Fereidouni et al. 2010). Our study suggests that subjects have experienced the effects of allergenic pollen; however, it could be that these effects only minimally disturb their everyday and outdoor leisure activities. The majority of study subjects (almost 74 % of cases) indicated in self-reports that they spend a rather long time outdoors, up to 6 h, during summer and autumn. It should be noted that more than 60 % of study subjects with a positive skin prick test for the allergens of *Betulaceae* family plants (Table 3) have been limiting their stay in an outdoor environment to up to 2 h in spring, during the working hours. However, the majority of these individuals prefer to stay outdoors for longer durations in weekends, ignoring the pollen levels in the air.

5 Conclusions

Our studies demonstrated a negative impact of pollen load on the quality of life of people of employable age in Lithuania. Admittedly, a large portion of study

subjects have disregarded the worsening of their quality of life caused by a load of allergenic pollen, and considered these ailments as their natural condition. This analysis of pollen load suggests that individuals could poorly associate their health disorders, potentially caused by the effects of pollen, with annual pollen dynamics, leading us to speculative a time span for effective impact identification. To the best of our knowledge, this is the first evaluation study in Lithuania, demonstrating the relations between pollen and the information presented in the self-reports of study subjects. The main strength of our study is a new synthesis of data on sensitivity to pollen among the Lithuanian population, and its impact on the quality of life. It became clear that society lacks accuracy and timeliness in identifying the disorders causing symptoms, and a resulting ignorance of allergy triggers results in worsening of quality of life and reduction in work efficacy. It is likely that the social awareness of the availability of a pollen hay fever diary, which could be a source of personally useful information, is poor (Berger et al. 2013). This tool could be especially useful in the cases analysed in this study involving tenfold differences in pollen load in certain years. In conclusion, this study demonstrated that people with pollen allergy have attributed symptom-associated worsening of their quality of life to the typical unavoidable hay fever periods and have made only minimal changes in their lifestyle during the season of pollen load.

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