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ORIGINAL ARTICLE

The dynamics of pollen seasons of the most allergenic plants - 15-year observations in Warsaw

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ABSTRACT:

Introduction: Allergic rhinitis concerns nearly 25% of the Polish population. Among pollen allergens, the most common reasons for allergic rhinitis are: grass, birch and mugwort. Knowledge of the characteristics of pollen seasons is necessary in diagnostics, monitoring of therapy and prevention of allergic rhinitis.

Purpose: This work aims to analyze pollen seasons of the most allergenic plants in the Polish population; grass, birch and mugwort in the years 2003–2017 in Warsaw.

Material and methods: Measurements of pollen concentration were carried out using Burkard volumetric spore trap operating in continuous mode. Analysis of pollen seasons was conducted based on the following characteristics: beginning, end, and length of season, the seasonal pollen index (SPI), defined as the sum of average daily pollen concentrations over the year, maximum daily concentration, number of days with maximum and threshold concentration. Linear regression together with the Pearson correlation coefficient were used in statistical analysis to study the relationship between variables; furthermore, descriptive characteristics of distributions studied were determined.

Results: The average beginning of the birch pollen season in the analyzed period is April 10th, and it belongs to seasons of medium length (47 days on average). Birch pollen count above 75 grains/m^3, when most allergic people develop symptoms, was recorded for an average of 18 days. The highest daily birch pollen count reaching 6321 grains/m^3 (2012) exceeded the lowest value of the maximum concentration by almost 20 times (2015). Among the taxa analyzed, the highest values of daily counts and annual sums were recorded for birch pollen. The average date for the beginning of grass pollination season is on May 13th. It is the longest pollen season (on average 134 days), and the period when concentration exceeded 50 grains/m^3 covered an average of 26 days. The highest daily grass pollen counts reaching 496 grains/m^3 (2007) exceeded the lowest value of maximum concentration by 3.5 times (2016). The average date of the beginning of mugwort pollen season is July 16th. The season lasts 65 days on average, when concentration exceeding 30 grains /m^3 was registered for an average of 12 days. The highest daily mugwort pollen count reaching 154 grains/m^3 (2007) exceeded the lowest value of maximum concentration by 4 times (2013). For all analyzed taxa, the strongest correlated variables are the sum of average daily pollen concentrations over the year (SPI) and daily maximum concentration (correlation for birch pollen = 0.92, for grass pollen = 0.88, and for mugwort pollen = 0.91).

Conclusions: Periods of pollen in the air show certain variation in the analyzed 15-year period. The maximum concentration in the pollen season for the analyzed taxa and the the sum of average daily pollen concentrations over the year show the highest variability, particularly strongly expressed in the case of birch pollen. There is a linear relationship between the sum of average daily pollen concentrations over the year and the maximum concentration value as well as the number of days with the threshold concentration for all analyzed taxa. Variability of parameters describing the dynamics of pollen seasons indicates the need to monitor, both by patients with hay fever and physicians, the current information on the concentration of pollen in the air during the pollen season.

KEYWORDS: allergic rhinitis, pollen monitoring, pollen count

INTRODUCTION

Rhinitis is a syndrome which affects an average of one third of the Polish population, and allergic rhinitis constitutes its significant proportion. Symptoms of allergic rhinitis were reported by nearly one quarter of respondents in the largest Polish epidemiological study [1]. This indicates the scale of the problem. The symptoms of allergic rhinitis are most often caused by pollen allergens, and grass, birch and mugwort pollen allergens are most sensitizing [2].

Knowledge coming from the aerobiological monitoring provides information on the exposure of people suffering from inhalation allergy to pollens which are the source of their symptoms. Knowledge of the dynamics of pollen seasons is essential in the diagnosis, monitoring of therapy and prevention of allergic rhinitis [3]. This information is of help for both the laryngologist, and allergologist in the care of a patient with rhinitis.

AIM

This paper aims to analyze pollen seasons of plants that are most allergenic in the Polish population; grass, birch and mugwort (Poaceae, Betula, Artemisia) in the years 2003–2017 in Warsaw.

MATERIAL AND METHODS

Measurements of pollen concentration were performed using Burkard spore trap operating in a continuous volumetric mode, placed at a height of 20 meters above ground level on a building located in Warsaw's Bielany district. Assessment was carried out in a 7-day cycle with the assessment of 24-hour periods. Microscopic analysis was performed using 4 horizontal stripes, and average daily pollen count was converted into 1 m^3 of air [4].

Pollen seasons of three taxa, which, according to epidemiological studies, are the most commonly sensitizing allergens in the Polish population: Betula (birch), Poaceae (grass) and Artemisia (mugwort), were analyzed [2]. Analysis of pollen seasons was based on the following characteristics: beginning, end and length of season, the sum of average daily pollen concentrations over the year (Seasonal Pollen Index), daily maximum concentration, number of days with maximum concentration and threshold concentration, responsible for the occurrence of allergy symptoms, marked for each of the taxa. Pollen seasons length was determined by 95% method, as the beginning and end of season assuming days in which respectively 2.5% and 97.5% of the annual sum of pollen grains were registered. This method eliminates low concentrations of pollen grains from the analysis at the beginning and end of season, usually originating from distant transport or redeposition [5, 6].

In statistical analysis, linear regression together with the Pearson correlation coefficient were used to analyze the relationship between the studied variables. Values of descriptive characteristics of the examined distributions were also determined, such as minimum value, maximum value and average value.

RESULTS

Pollen monitoring conducted in 2003–2017 enabled the characterization of pollen seasons of taxa whose allergens are the most common cause of pollen allergy. Table I demonstrates the basic data which characterize the course of pollen seasons of birch, grass and mugwort. The following were considered; beginning and end of pollen seasons, duration, annual sums of concentrations and days with maximum daily concentration and concentration exceeding threshold values. Data analysis indicates the variability of such characteristics as the beginning and duration of the season, the value of the maximum pollen concentration in the season and the sum of average daily pollen concentrations over the year (Seasonal Pollen Index).

Birch (Betula)

Allergens of birch pollen pose the greatest threat in central Poland in April. In the analyzed period, the average beginning of birch pollen season is April 10. The earliest that the pollen season had started is March 29 (2014), and the latest April 23 (2013). Extreme dates of beginning of pollen season were 24 days apart. In the past fifteen years, the average date of the end of birch pollen season was April 29. The earliest end of birch pollen season was April 17 (2017), and the latest was May 8 (2006). In this case, the difference was also large and amounted to 20 days (Tab. I).

The threshold concentration of birch pollen at which the first symptoms appear in people allergic to these allergens was assessed for the Polish population as 20 grains/m^3 of air [7]. The average length of the period when concentration of birch pollen grains exceeded the above threshold value was 27 days. On the other hand, high concentration, exceeding 75 grains/m^3, when in the most sensitized people, symptoms should be expected [7], were recorded within 18 days on average. The highest number of days with a high concentration of birch pollen, exceeding 75 grains/m^3, was recorded in 2001–2002 and 2014 (Fig. 1).

The highest daily concentrations of birch pollen were recorded in 2006, 2012 and 2016, reaching 6321 grains/m^3 of air

Tab. I. Basic variables characterizing the pollen seasons of birch, grasses and mugwort (Betula, Poaceae, Artemisia) in Warsaw air in the years 2003–2017.

TAXON		BEGINNING OF SEASON (95%)	END OF SEASON (95%)	LENGTH OF SEASON (DAYS)	MAXIMUM CONCENTRATION OF POLLEN GRAINS (Z/M³) / DATE	NUMBER OF DAYS WITH CONCENTRATION ABOVE THRESHOLD*	THE SUM OF AVERAGE DAILY POLLEN CONCENTRATIONS OVER THE YEAR (SPI VALUE)
	X av	10.04	29.04	47	2476	27	14249
Birch	Min	29.03 (2014)	17.04 (2017)	30 (2015)	322 (22.04.2015)	13 (2013)	2355 (2015)
	Max	23.04 (2013)	08.05 (2006)	63 (2012)	6321 (22.04.2012)	36 (2008,14,16)	32083 (2016)
	X av	13.05	9.08	134	220	52	4061
Grass	Min	1.05 (2012)	20.07 (2007,17)	66 (2003)	113 (5.06.2016)	43 (2013)	2630 (2004)
	Max	25.05 (2005)	12.09 (2015)	174 (2012)	469 (19.06.2007)	64 (2008)	6167 (2007)
	X av	16.07	28.08	65	85	12	1103
Mugwort	Min	10.07 (2012)	8.08 (2017)	20 (2017)	42 (7.08.2013)	5 (2017)	361 (2017)
	Max	22.07 (2004)	6.09 (2009,11)	82 (2011)	154 (8.08.2007)	23 (2007)	2013 (2007)

*Threshold concentration at which the first clinical symptoms are expected in people allergic to given allergen (description in text)

(April 22, 2012). It exceeded the lowest value of the maximum concentration recorded on April 22, 2015 by several times (Tab. I). Similar observations concern the sum of average daily pollen concentrations over the year (SPI). The longest birch pollen season took place in the years 2008, 2012 and 2014 (Fig. 1).

Significant relationships between the characteristics of birch pollen seasons are shown in Figure 2. The strongest correlation was demonstrated for the sum of average daily pollen concentrations over the year (SPI) and daily maximum concentration in a given season (correlation = 0.92). The sum of average daily pollen concentrations over the year (SPI) is also correlated with the number of days above the threshold concentration (correlation = 0.63) and the number of days above 75 grains/m^3 (correlation = 0.77).

The following are regression equations describing relationships shown in Fig. 2.

- SPI (total) = 1560.3010 + 5.1244 x max. daily concentration (peak value), R2 2=0.84 (p=1.59e-06)
- SPI (total) = -9696.0 + 900.2 x days with concentration >20 grains/m^3 (days20), R2 2 = 0.40 (p=0.0117)
- SPI (total) = -7140.7 + 1137.7 x days with concentration >75 grains/m^3 (days75), R2 2=0.59 (p=0.000883)

Grass (Poaceae)

Grass pollen may appear in Warsaw air as early as the beginning of May, and may be present even until mid-September. In the analyzed 15-year period, the average beginning of grass pollen season was May 13th. The earliest that grass pollen season started was May 1 (2012), and the latest May 25 (2005) (Tab I). The difference in the beginning of pollen season in extreme years was 24 days. The average date of the end of grass pollination season was in the assessed period on 9 August. The earliest end of grass pollen season was on July 20 (2007 and 2017), and the latest on September 12 (2015). Here the difference was very large and amounted to over one and a half months. Grass pollen season is the longest pollen season, which is a source of highly sensitizing allergens, with an average duration of 134 days.

Threshold concentration of grass pollen at which the first symptoms appear in people allergic to these allergens, was assessed for the Polish population at 20 grains/m^3 of air [7]. The average length of the period when the concentration of grass pollen grains exceeded the above threshold value was 52 days, so twice as long as in the case of the birch pollen season. On the other hand, high concentration for grass, exceeding 50 grains/m^3, when in the most sensitized people symptoms should be expected [7], were recorded within 26 days on average. The largest number of days with pollen grains exceeding 50 grains/m^3, amounted to 39 days, and was recorded in 2010 (Fig. 1).

The highest daily concentrations of grass pollen were registered in 2005 and 2007 and reached 469 grains/m^3 of air. It exceeded the lowest value of maximum concentration recorded on June 5, 2016 by 4 times (Tab. I). The highest concentrations of grass pollen are recorded in June, until the beginning of July. Similar observations concern the sum of average daily pollen concentrations over the year (SPI). The longest grass pollen season took place in 2012 and 2015 (Fig. 3).

Significant relationships between the characteristics of grass pollen seasons are shown in Figure 4. The strongest correlation was demonstrated for the sum of average daily pollen concentrations over the year (SPI) and daily peak concentration in a given season (correlation = 0.88), and for the sum of average daily pol-

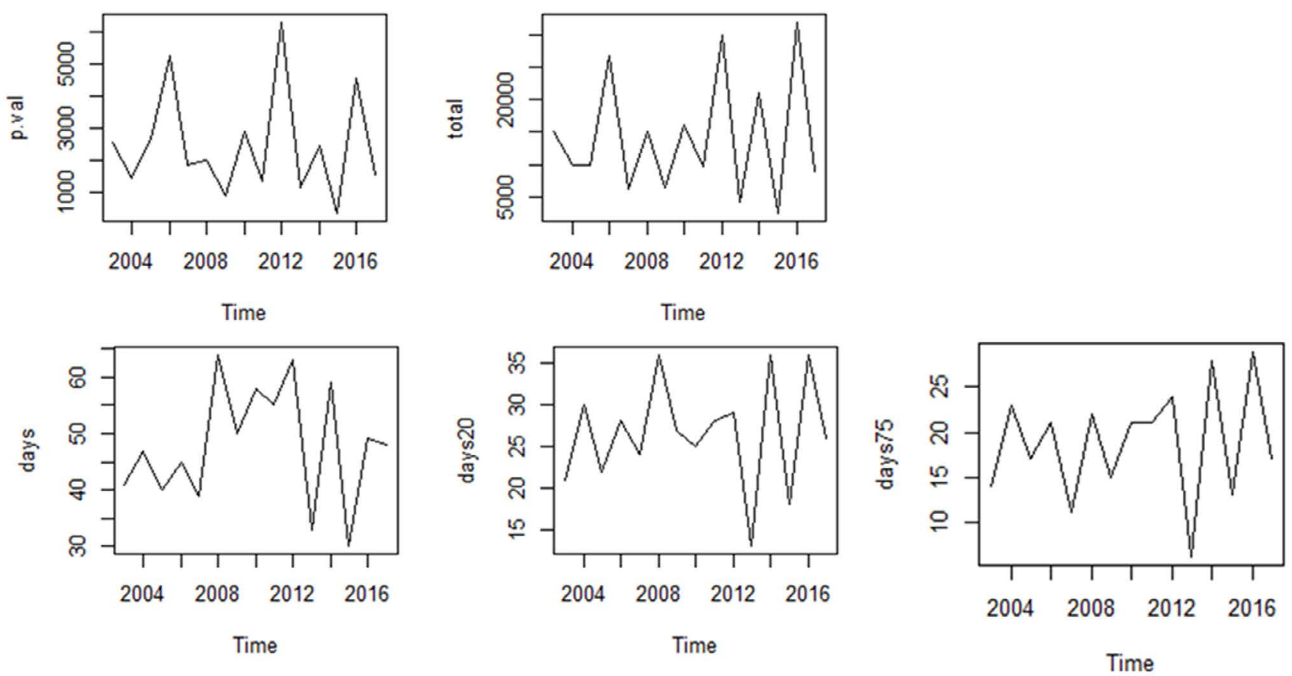

Fig. 1. Variability in time of individual variables characterizing birch pollen seasons in the years 2003–2017 in Warsaw air (p.val; peak value – maximum concentration, total – the sum of average daily pollen concentrations over the year (SPI), days – length of pollen season, days20 – number of days with concentration above threshold 20 grains/m³, days75 – number of days with concentration above 75 grains/m³).

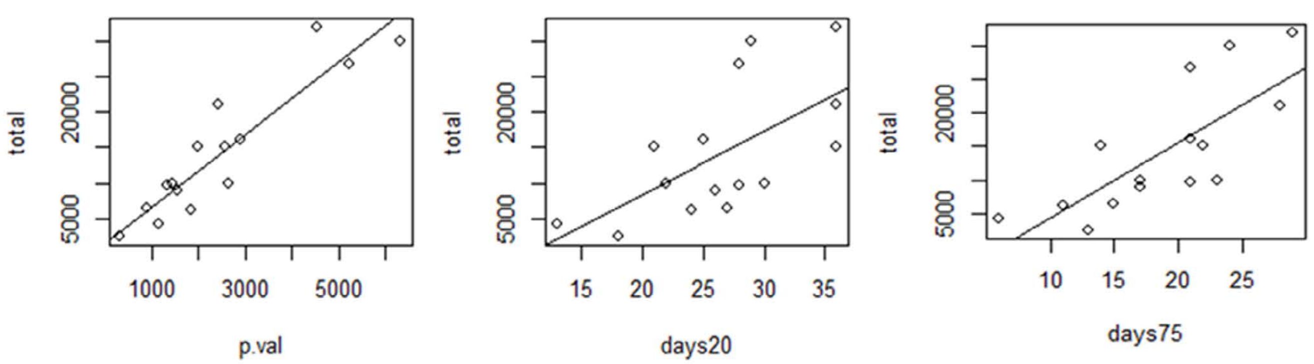

Fig. 2. Correlations between individual variables characterizing birch pollen seasons in 2003–2017 in Warsaw (p.val; peak value – maximum concentration, total – the sum of average daily pollen concentrations over the year (SPI), days20–number of days with concentration above threshold 20 grains/m³, days75 – number of days with concentration above 75 grains/m³).

len concentrations over the year (SPI) and the number of days with concentrations above 50 grains/m³ (correlation = 0.79).

The following are regression equations describing relationships shown in Fig. 4.

- SPI (total)= 2097.049 + 8.923 x max. daily concentration (peak value), R2 2=0.78 (p=1.25e-05)
- SPI (total) = 1006 + 115 x days with concentration >50 grains/m³ (days50), R2 2= 0.62 (p=0.0005)

Mugwort (Artemisia)

Artemisia pollen is registered in the air since the middle of July. In the analyzed 15-year period, the average beginning of mugwort pollen season was July 16. The earliest that mugwort pollen season started was July 10 (2012), and the latest

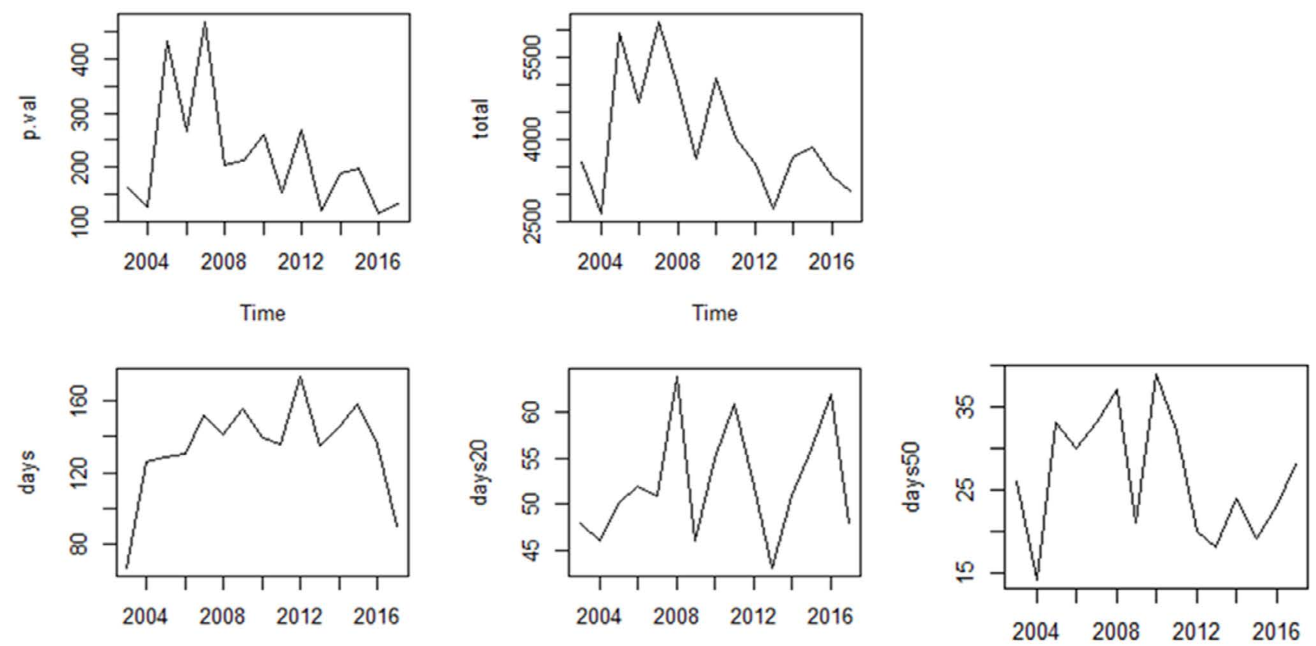

Fig. 3. Correlations between individual variables characterizing grass pollen seasons in 2003–2017 in Warsaw (p.val;peak value – maximum concentration, total – the sum of average daily pollen concentrations over the year (SPI), days – length of pollen season, days20 – number of days with concentration above threshold 20 grains/m³, days50 – number of days with concentration above 50 grains/m³).

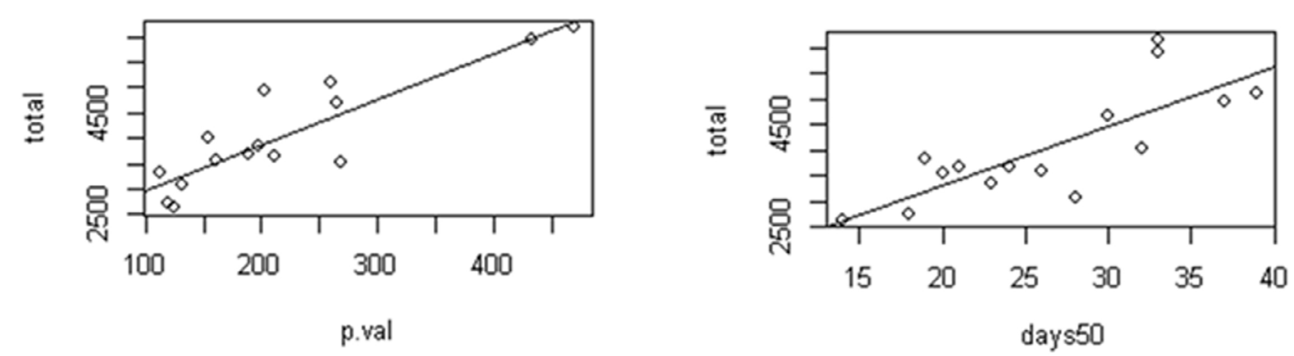

Fig. 4. Correlation between individual variables characterizing the pollen seasons of grasses in years 2003–2017 in Warsaw (p.val; peak value – maximum concentration, total – the sum of average daily pollen concentrations over the year, days50 – number of days with concentration above 50 grains/m³).

July 22 (2004) (Tab I). Extreme dates of beginning of pollen season were 12 days apart. The difference in the end of the pollen season was much bigger. The average date of the end of mugwort pollination season in the previous fifteen-year period was 28 August. The earliest end of mugwort pollen season was August 8 (2017), and the latest was September 6 (2009, 2011). In this case, the difference was almost a month. The shortest season was recorded in 2017, and lasted only 20 days, the longest in 2011 – 82 days. The difference between extreme values was 62 days.

The threshold concentration of mugwort pollen at which symptoms appear in people allergic to these allergens, was estimated for the Polish population at 30 grains/m³ of air [7]. The average length of the period when concentration of mugwort pollen grains exceeded the above threshold value was 12 days (Tab. I).

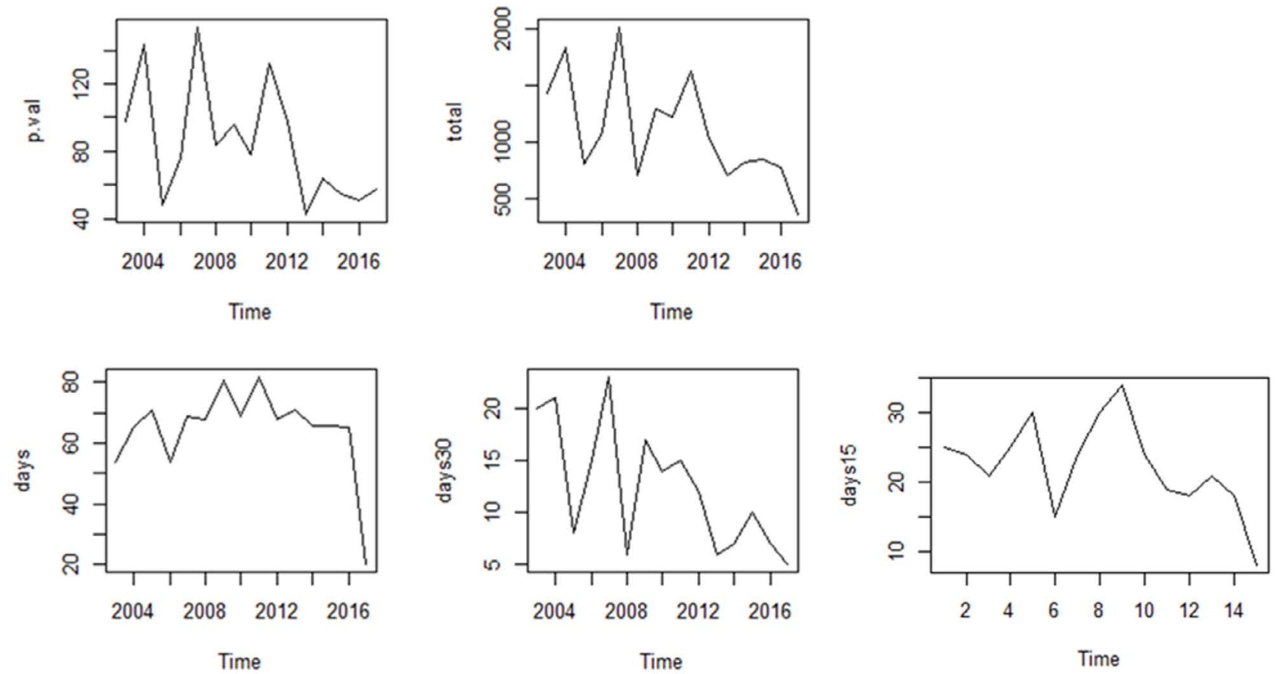

Fig. 5. Variability in time of individual variables characterizing pollen seasons of mugwort in years 2003–2017 in Warsaw air (p.val; peak value – maximum concentration, total – the sum of average daily pollen concentrations over the year, (SPI), days – length of pollen season, days30 – number of days with concentration above threshold 30 grains/m³, days15 – number of days with concentration above 15 grains/m³).

The decreasing tendency of this feature has made itself visible over the years (Fig. 3). The period when mugwort pollen concentration was over 15 grains/m³ was 22 days on average. The highest daily concentration of Artemisia pollen was recorded in 2007, reaching 154 grains/m³ of air (8.08). It exceeded the lowest value of maximum concentration by 3.5 times (2013) (Tab. I). Similar observations concern the sum of average daily pollen concentrations over the year (SPI) (Fig. 5).

Significant relationships between characteristics of pollen seasons are presented in Fig. 6. The strongest correlation was demonstrated for the sum of average daily pollen concentrations over the year (SPI) and the daily maximum concentration in a given season (correlation = 0.91), and for the sum of average daily pollen concentrations over the year (SPI) and number of days with concentration above 30 grains/m³ (correlation = 0.94), as well as between the daily maximum concentration in the season and the number of days with concentrations above 30 grains/m³ (correlation = 0.83). Very strongly correlated was also the sum of average daily pollen concentrations over the year (SPI) and the number of days with concentrations above 15 grains/m³ (correlation = 0.82), (Fig. 6).

The following are regression equations describing relationships shown in Figure 6.

- SPI (total) = 93.271 + 11.878 x max. daily concentration (peak value), R2 2=0.83 (p=2.25e-06)
- SPI (total) = 206.595 + 72.344 x days with concentration >30 grains/m³ 30, R2 2=0.89 (p=1.55e-07)
- max. daily concentration (peak value) = 23.6946 + 4.9494 x days with concentration >15 grains /m³, R2 2=0.71 (p=8.97e-05)
- SPI (total) = -200.73 + 58.23 x days with concentration >15 grains/m³, R2=0.67 (p=0.000177)

DISCUSSION

Allergic rhinitis belongs to very frequent diseases in the group of children, adolescents and young adults. This indicates the need to implement large-scale activities leading to early detection and prevention. Pollen monitoring provides access to information on the course of pollen seasons in particular years and current information on current and forecasted exposure to aeroallergens. This information is important for both the patient and the doctor. They allow the patient to self-monitor his allergy symptoms, which is necessary in comprehensive diagnosis of allergic rhinitis and prophylaxis. The doctor makes use of this information by making a diagnosis, requesting symptomatic treatment and assessing its effectiveness and by conducting allergen specific immunotherapy [8, 9, 10]. An element that also requires consideration in the care of patients with allergies is air pollution, additionally affecting reactivity of the mucous membrane and sensitizing potential of pollen [11, 12].

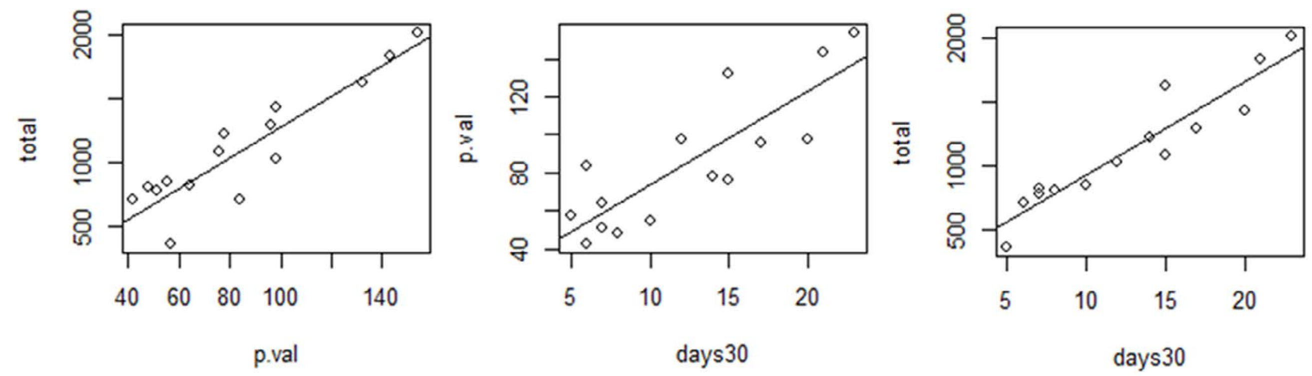

Fig. 6. Variability in time of individual variables characterizing pollen seasons of mugwort in years 2003-2017 in Warsaw (p.val; peak value – maximum concentration, total – the sum of average daily pollen concentrations over the year (SPI), days30 – number of days with concentration above threshold 30 grains/m3, days15 – number of days with concentration above 15 grains/m³).

Pollen season is characterized by variability in individual years, both in terms of duration and the achieved concentration of pollen [13]. Primarily pollen seasons of trees, but also grasses and mugwort are characterized by high variability. European studies indicate the differentiation of dates of the beginning of pollen seasons of grass and mugwort in subsequent years, especially in relation to weather conditions [14].

The beginning of birch pollen season in Warsaw was on average April 10, and particular years showed certain variation. Long-term monitoring performed in Sosnowiec shows that the beginning of birch pollen season took place a few days earlier, on average 97 day of the year (6 April) and showed small differences in individual years [15]. Similar results were obtained in Wrocław [16]. Similarly to the Silesian studies, in our research, the length of birch pollen season was highly variable. Analysis of the relationship between weather conditions and variables characterizing pollen seasons has shown the influence of, among others, high temperature and relative humidity to the degree of intensity and the course of tree pollination [17, 18, 19].

Analysis of the length of pollen seasons showed that the average length of the pollen season for studied taxa was the lowest for birch and amounted to 47 days. Thus, the birch pollen season can be classified as a medium season, since it falls in the range of 35–60 days [5]. Birch pollen may stay in the air for some time after the end of the relevant season, as a result of the so-called redeposition or distant pollen transport [5]. Distant transport of birch pollen has been confirmed in many studies [20]. The length of grass and mugwort pollen seasons allows them to be recognized as long seasons, in the range of 60–120 days [5]. The longest average pollen season was found for grasses (134 days). This is in line with observations from monitoring carried out in other regions of Poland [15, 21, 22]. Grass pollen is recorded in the air from May to September, with the highest concentrations recorded in June, until the beginning of July. Severity of symptoms increases in people allergic to grass pollen during this period. The long period of grass pollination is associated with the occurrence of a very large number of species belonging to the family Poaceae, which flowering occurs in different months of plants' growing season [23].

Compared to other taxa studied, birch reached the highest annual sums and their very large variation in individual years. Very large diversity of this feature was also observed by other researchers, including in Kraków [5], in Sosnowiec [15]. Also the maximum daily concentration values showed much greater variations for birch compared to other analyzed taxa.

In the second half of the analyzed 15-year period, in the assessment of variables characterizing mugwort pollen season, there was a reduction in the number of days above the threshold concentration and the value of maximum concentrations. Changes observed can be influenced by changes in spatial development of the city, related to the development of previously undeveloped sites, and thus the reduction of areas overgrown with ruderal vegetation. Studies comparing the presence of mugwort pollen in areas with varying degrees of urbanization clearly indicate a higher risk of exposure to mugwort allergens in rural areas compared to urban agglomerations [24].

Over the analyzed years, linear relationships have been observed between the value of the seasonal pollen index (SPI), i.e. the sum of average daily pollen concentrations over the year

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and the maximum concentration value and the number of days with the threshold concentration for all analyzed taxa.

Variability of parameters describing the dynamics of pollen seasons indicates the need to monitor current information regarding the concentration of pollen in the air during the season. Updated addresses of websites with data available to both patients and doctors, can be found at www.alergen.info.pl.

CONCLUSIONS

Analysis of pollen seasons in Warsaw in 2003–2017 allows to put forward the following conclusions:

- Birch pollen allergens pose the greatest threat in April. Grass pollen is present in the air from May till the beginning of September, with the highest concentrations in June. Mugwort pollen is recorded in the air from mid-July to the beginning of September, with the highest concentration in the first half of August. Periods of pollen appearing in the air show certain variation in the analyzed 15-year period.
- The highest variability is shown in maximum concentration in the pollen season for all analyzed taxa and the sum of average daily pollen concentrations over the year (SPI), particularly strongly expressed in the case of birch pollen.
- There is a linear relationship between the sum of average daily pollen concentrations over the yea and the maximum concentration value and the number of days with the threshold concentration for all analyzed taxa.
- Variability of parameters describing the dynamics of pollen seasons indicates the need to monitor, both by patients with inhalation allergy and physicians, current information regarding the concentration of pollen in the air during the pollen season.

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