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Development of a symptom load index: enabling temporal and regional pollen season comparisons and pointing out the need for personalized pollen information

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Abstract This study describes the development of an index, the symptom load index, to compare the severity of pollen seasons for pollen allergy sufferers during different seasons in different geographical regions. This is done by comparing symptom data with pollen data. This study is based on symptom data of the Patients' Hayfever Diary (PHD) and on pollen data from the European Aeroallergen Network (EAN). The PHD allows objective assessment of the season severity. Season length calculated on the basis of pollen data from the EAN and all records of users in a specific region are included in calculation of the symptom load index. It is thus not influenced by pollen counts during the season. Its application to pollen seasons of the three important pollen types birch, grass and ragweed in Austria and Germany from 2009 to 2013 proved that the impact of a pollen season on allergy sufferers is not correlated with total pollen loads. The possibility to calculate the pollen season in the allergy sufferers' point of view is a novelty that inaugurates new pathways for the future of pollen information. Furthermore, such an index will be of

value for the establishment of personalized pollen information and for calculations of pollen thresholds.

Keywords Symptom load index · Computation of pollen season severity · Pollen allergy · Pollen count information · Patient's Hayfever Diary

Abbreviations

APL Annual pollen load
EAN European Aeroallergen Network
PHD Patient's Hayfever Diary
SLI Symptom load index

1 Introduction

Pollen allergy is a major problem for a considerable percentage of people all over Europe. The current prevalence rates of allergic rhinitis and allergic asthma range from 5 to 30 % in industrialized countries (Asher et al. 2006). Furthermore, the prevalence of pollen-induced allergies is increasing (D'Amato et al. 2007). Pollen information is an important pillar in supporting pollen allergy sufferers (Gonzalo-Garijo et al. 2009; Karatzas 2009). The state of the art of pollen monitoring and pollen information services is summarized in Karatzas et al. (2013). Today, pollen information tries to answer the question of how the pollen season will develop in the current year and provides pollen forecasts based on pollen counts

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(Levetin and Van de Water 2003). The resulting question, namely what impact airborne pollen has on allergy sufferers during the pollen season, has seldom been approached in detail. Recent developments in the scientific field, such as the threshold discussion (De Weger et al. 2013; COST action ES0603 n.d.), suggest that each individual may react differently during the season (Berger et al. 2013). In addition, different pollens seem to induce different symptom load levels, e.g., poplar pollen has been found to cause milder symptoms than grass pollen in sensitized persons in Ankara (Celik et al. 2005). However, proper comparisons between pollen seasons for the individual or for populations have thus far seemed to be out of reach.

Furthermore, it is necessary to develop a new approach due to the inconsistencies in classic pollen information relying solely on pollen counts. Buters et al. (2012) recently observed that the allergen content (Bet v1) in birch pollen is not always correlated with the total amount of birch pollen in the air. Galán et al. (2013) have also observed that airborne olive pollen counts are not always representative of exposure to the major olive allergen (Ole e 1) in southern Europe. Consequently, the HIALINE project studies have argued that there is a difference in exposure to allergens and pollen counts (Buters et al. 2012; Galán et al. 2013). However, pollen forecasts based on pollen counts are the most common and prevalent pollen information tool for pollen allergy sufferers. In order to improve pollen information, it is important to consider a range of imperfections of pollen counting and of pollen forecasts. Pollen counts depend on different types of pollen traps, different elevations of monitoring stations and different preparation methods. Furthermore, pollen forecasts may not be accurate due to (1) distances between the pollen trap and the domicile of an allergy sufferer, (2) the duration of outdoor activities, (3) aeroallergen versus pollen potency (4) the possible influence of fine particulates and ozone on symptom severity and (5) the influence of medication on symptom severity. Inclusion of these factors is costly and/or difficult to monitor; such issues have to be overcome.

Because allergies instantly cause symptoms when the allergy sufferer is in contact with a sufficient amount of the allergen, it seems logical to try a totally different method and seek information from the allergy sufferers themselves. In addition, pollen loads alone are not the only determinant of the severity of

symptoms in the allergy sufferer. So far, the only similar approach to that adopted here was to test the predictability of symptom severity in a given season in selected patients with pollen-induced rhinoconjunctivitis (Radcliffe et al. 2006). The authors found a high level of reproducibility for both the quantitative skin prick test and the conjunctival provocation test. In contrast, Ellis et al. (2010) found no correlation between symptomatic responses and the degree of skin prick testing reactivity. Blood thymus and activation-regulated chemokine levels have also been used as parameters for assessing the severity of allergic disorders (Xiao et al. 2007). All these examinations are consuming in terms of both time and cost. However, the Patient's Hayfever Diary (PHD) offers an objective tool that is free and web-based and gathers data from a large sample of users. It documents symptoms from different users over different seasons and different geographic regions and calculates the influence of medication. It is clear that an opportunity to define the severity of a pollen season is afforded by comparing the airborne pollen amount with the symptom data of PHD users. A similar approach was already taken by Sánchez Mesa et al. (2005) to examine the contribution of different aeroallergens to allergic symptoms in the allergic population. The main aim of this study is to develop an index to compare season severity and apply it to the main aeroallergens of birch, grass and ragweed in pollen seasons from 2009 to 2013 in Austria and Germany.

2 Materials and methods

The PHD (www.pollendiary.com) is a web-based tool for people suffering from pollen allergy and asthma developed in cooperation with the Austrian Pollen Information Service, the Stiftung Deutscher Polleninformationsdienst, Réseau National de Surveillance Aérobiologique France, the ORL Department at Vienna Medical University and the Allergy-Centre-Charité Berlin (Berger et al. 2011). PHD users input data concerning their location, pollen-induced nasal, ocular and respiratory symptoms and relevant medication use. The PHD system is linked to the European Aeroallergen Network (EAN) database (<https://ean.polleninfo.eu/Ean/>) maintained by the Medical University of Vienna.

PHD users are not only able to keep a diary of their personal symptoms, but they can also produce graphs of their symptoms and corresponding pollen levels recorded in the regions where they are situated (Voukantsis et al. 2012). PHD data are highly useful for research, such as examining spatial variations in threshold values for aeroallergens (i.e., the number of pollen grains per cubic meter of air necessary to cause symptoms). The system allows the reporting of pollen-induced symptoms and relevant medication use by allergy sufferers throughout Europe (Voukantsis et al. 2012) and is currently available in 13 countries (Austria, Croatia, Finland, France, Germany, Hungary, Lithuania, Serbia, Slovenia, Sweden, Switzerland, Turkey and the United Kingdom). To date (2009–2013), more than 40,000 users have entered data into the system. The large number of users and wide geographical coverage of PHD therefore allows comparison of data between regions. The study aims to gain a first overview of symptom loads and therefore users were not filtered. We focused on the severity of pollen seasons in the period 2009–2012 or until 2013 for the major allergenic pollen types—birch, grasses and ragweed—in Austria and Germany. The result is the comparison of the symptom load index (SLI) with the annual pollen load (APL).

2.1 Patient's Hayfever Diary (PHD) user process

Eyes, nose and lungs are the three organs of interest. For each organ, a severity score from zero to three is possible, resulting in a maximum of nine points for all organs. The scores are as follows:

- No discomfort (no problems) = 0
- Low discomfort (mild problems) = 1
- Moderate discomfort (moderate problems) = 2
- Strong discomfort (severe problems) = 3

In addition, four specific symptoms can be identified for each organ. Each of these symptoms adds one point. Therefore, the maximum score of four points for each organ results in a maximum overall specific symptom score of twelve points. The specific symptoms are: itching, foreign body sensation, redness and watering for the eyes; itching, sneezing, running and blocked for the nose; wheezing, shortness of breath, cough and asthma for the lungs. Although asthma is a disease or condition rather than a symptom (NAEPP 2007), due to its importance and connection to

allergies, it was decided to include it. By doing so, it is possible to collect data on the disease (condition).

As well as the total of 21 points covering discomfort and specific symptoms, the weighted medication score awards additional points for different medication types. Eye drops have an impact on the eyes, but not on the lungs, whereas tablets have an impact on all organs. For this reason, it was decided to use weighted medication. The scoring system is as follows:

Eye medication comprises a total of 1.8 points: one point for “Eye drops” or “Tablets” or both; 0.5 points for “Others”; 0.3 points for “Homeopathic”. Nose medication comprises a total of 2.05 points: one point for “Nose drops” or “Tablets” or both; 0.25 points for “Eye drops”; 0.5 points for “Others”; 0.3 for “Homeopathic”.

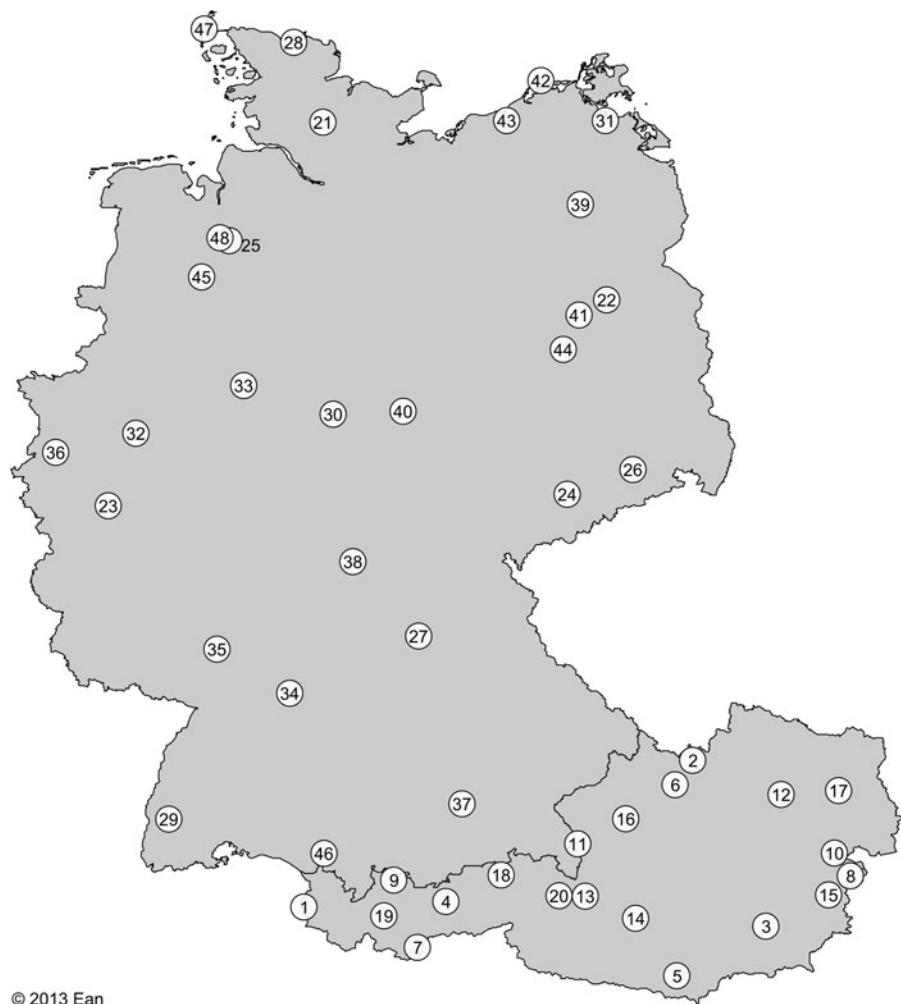
Lung medication comprises a total of 0.8 points: 0.25 points for “Tablets” and for “Others”; 0.3 points for “Homeopathic”.

Thus, the total weighted medication score is 4.65, and the total number of points related to the symptoms and medication use ranges from 0 to 25.65.

2.2 Calculation of the APL and the SLI

Pollen data were requested from the EAN database. All members use the Hirst-type spore trap (Hirst, 1952) and follow the minimum recommendations proposed by Jäger (1995). As a first step, only pollen traps that were active throughout the pollen seasons from 2009 to 2013 were included in the region “Austria” and “Germany” to avoid data bias due to missing data. Data from 20 pollen traps were used for Austria and from 28 for Germany (Fig. 1; Table 1). Pollen measurement sites are well distributed throughout the two countries, and their location is shown in Fig. 1. Airborne pollen was expressed as annual pollen load (APL) for different pollen types (*Betula*, Poaceae and *Ambrosia*) and different regions (Austria and Germany, Table 2). As a first step, the annual sum of daily or bi-hourly counts of individual stations were determined to calculate the APL. These were averaged and rounded off to avoid decimal pollen values (Table 2). These averages were used for comparison with the SLI. The APL is expressed in pollen per m³. Statistical values (mean, standard deviation and variation coefficient) can be found in Table 3.

Fig. 1 Location of pollen monitoring sites included in this study in Austria and Germany. The *numbers* refer to the respective stations in Table 1



The PHD provides a lot of data, and for this study, a total of 293,098 entries were used. The users were not filtered, meaning that each entry was included in the study. In our experience, users only enter data when they experience symptoms. The number of entries used is listed per year, region and pollen type in Table 2. Symptom data from a specific region over a defined period, the principal pollination period (PPP), were requested. The EAN definition of the PPP was adopted: beginning with 1 % and ending with 95 % of the yearly sum of a pollen count. The symptom data in this period were calculated from all symptom records per day in the region (sum of all records divided by number of users). Daily values were taken into account to calculate the season average. The result is completely independent from pollen count data, except for

the season definition. The SLI values calculated for this study are in Table 2.

3 Results

3.1 Birch pollen seasons from 2009 to 2013

In the case of birch in Austria, the SLI starts with values no lower than 4.5 and reaches a maximum of 5.9 within the studied period (Fig. 2; Table 2). During 2009 and 2010, the SLI increases with the pollen loads. In 2011, the SLI is higher than in the previous years, although the pollen loads are lower than in 2010. In 2012, the highest pollen loads, heading toward 9,000, are observed within the examined

period, but the SLI drops down to its minimum. In 2013, the SLI increases dramatically to reach its maximum although the pollen loads are on average lower than 6,000.

In Germany, a similar pattern and similar values in the SLI can be observed (Fig. 2). Values range from 4.5 to 5.6. During 2009, the SLI does not correspond to the total pollen loads and this is repeated until 2011. In 2012, there is a drop in the total pollen count, as well as in the SLI. In 2013, both indices increase. The SLI reaches its maximum in 2011 and is similarly high in 2013. Only in 2012 does the APL correspond well with the SLI, completely unlike the situation in Austria.

3.2 Grass pollen seasons from 2009 to 2012

Over the whole period from 2009 to 2012 in Austria, the SLI values are in contrast to the APL, resulting in the mirrored appearance of the graphs (Fig. 3; Table 2). The SLI during the grass pollen season is

Table 1 Pollen traps included in the regions “Austria” and “Germany” were checked to deliver data over all pollen seasons from 2009 to 2013

Region	Pollen traps included
Austria	(1) ATFELD Feldkirch (2) ATFREI Freistadt (3) ATGRAZ Graz (4) ATINNS Innsbruck (5) ATKLAG Klagenfurt (6) ATLINZ Linz (7) ATOBER Obergurgl (8) ATPULL Oberpullendorf (9) ATREUT Reutte (10) ATROSA Rosalia (11) ATSALZ Salzburg (12) ATSTPO St. Pölten (13) ATSVPG St. Veit im Pongau (14) ATTAMS Tamsweg (15) ATTATZ Bad Tatzmannsdorf (16) ATVOEC Vöcklabruck (17) ATWIEN Wien (18) ATWOER Wörgl (19) ATZAMS Zams (20) ATZELL Zell am See

Table 1 continued

Region	Pollen traps included
Germany	(21) DEAUKR Aukrug (22) DEBERL Berlin (23) DEBONN Bonn (24) DECHEM Chemnitz (25) DEDELM Delmenhorst (26) DEDRES Dresden (27) DEERLA Erlangen (28) DEFLEN Flensburg (29) DEFREI Freiburg (30) DEGOET Göttingen (31) DEGREI Greifswald (32) DEHAGE Hagen (33) DELIPP Bad Lippspringe (34) DELOEW Löwenstein (35) DEMANN Mannheim (36) DEMOEN Mönchengladbach (37) DEMUNC München (38) DEMUST Münnerstadt (39) DENEST Neustrelitz (40) DENEUS Neustadt/Südharz (41) DEPOTS Potsdam (42) DEPRER Prerow/Darß (43) DEROST Rostock (44) DETREU Treuenbrietzen (45) DEVECH Vechta (46) DEWANG Wangen (47) DEWEST Westerland/Sylt (48) DEWLOG Westerlog

Numbers refer to the map (Fig. 1)

not as variable as in the case of birch and ranges from 3.3 to 3.9 within the observed period, showing the highest value in 2009 and the lowest in 2011. Curiously, the maximum pollen loads in 2011 occur together with the minimum SLI values, and the minimum pollen loads occur together with the maximum SLI values.

In Germany, the situation is entirely different (Fig. 3). The SLI is more variable and ranges from 3.4 to 4.7. However, the maximum also occurs in 2009 and the minimum in 2011, similar to Austria. The minimum SLI value is also correlated with the lowest APL. In this case, the graphs seem to correspond to a considerable extent.

Table 2 APL and SLI values of the regions included per year, and aeroallergens and the respective number of entries used

Region	Pollen type	Year	APL	SLI	PHD entries
Austria	<i>Betula</i>	2009	3,484	4.71	13,971
		2010	6,282	5.12	8,734
		2,011	4,555	5.35	16,223
		2012	8,836	4.56	16,508
		2013	5,880	5.93	21,943
	Poaceae				77,379
		2009	2,523	3.96	13,550
		2010	2934	3.58	15,132
		2011	2,965	3.34	29,287
		2012	2,464	3.57	16,470
	<i>Ambrosia</i>				84,439
		2009	282	3.96	2,666
		2010	170	2.50	6,918
		2011	240	2.35	15,111
		2012	259	3.06	5,859
	Austria total				30,554
					192,372
Germany	<i>Betula</i>	2009	5,887	5.41	528
		2010	8,251	4.88	2,110
		2011	5,227	5.69	7,528
		2012	4,775	4.54	10,411
		2013	6,526	5.63	13,673
	Poaceae				34,400
		2,009	1,853	4.78	2,034
		2,010	1,689	4.17	4,802
		2,011	1,545	3.43	16,289
		2012	1,804	4.09	22,804
	<i>Ambrosia</i>				45,283
		2009	25	4.33	454
		2010	21	3.03	3,419
		2011	10	2.75	9,959
		2012	10	3.23	6,715
	Germany total				37,521
					100,726

The total number of entries for the whole period of the birch, grass and ragweed pollen seasons and the total number for each region are given in bold. Note the different amounts for birch, grasses and ragweed between the two regions, Austria and Germany

Table 3 Mean, standard deviation and variation coefficient for the presented data per pollen type and region

Region	Pollen type	Mean	Standard deviation	Variation coefficient
Austria	<i>Betula</i>	5,047,4	4,693,1	0.9
	Poaceae	2,302,2	1,332,4	0.6
	<i>Ambrosia</i>	165,6	310,7	1.9
Germany	<i>Betula</i>	5,657,5	5,065,5	0.9
	Poaceae	1,664,4	1,302	0.8
	<i>Ambrosia</i>	19,4	41,2	2.1

3.3 Ragweed pollen seasons from 2009 to 2012

In Austria, the SLI for *Ambrosia* varies considerably and ranges from 2.3 to 3.9, but does not reach the values calculated for birch (Fig. 4). It starts off at its maximum value in 2009 and in 2010 drops following the APL. The lowest SLI value is observed in 2011, although during this year, the APL increases dramatically compared to the previous year. In 2012, the SLI and the APL both increase.

In Germany, there is clearly no correspondence between the SLI and the total pollen load over the whole period from 2009 to 2012 (Fig. 4), although the relationship is better than in Austria. The SLI ranges from 2.7 to 4.3. The progression of the SLI graph is the same as in Austria in 2009 and 2010, but different during 2011. A drop in the SLI and in the APL can be observed. The maximum is observed in 2009, the minimum in 2011 and in 2012, it increases again.

3.4 SLIs for birch, grass and ragweed pollen in Austria and Germany

When the SLIs of the three pollen taxa, birch, grasses and ragweed, are compared within a region, it is clear that allergy sufferers seem to suffer most from birch pollen (Fig. 5). Both in Austria and in Germany, the SLI of birch exceeds the values for grasses and ragweed from 2009 to 2012 (Figs. 2, 5). Interestingly, symptom loads caused by ragweed are the lowest (Figs. 4, 5). However, it has to be emphasized that the APLs of ragweed are very low across Germany (Fig. 4; Table 2).

Concerning the relationship between SLI and APL, only grasses seem quite strictly to induce pollen-load-dependent symptoms, meaning the APLs and the

Fig. 2 SLI (continuous lines) compared to APL (dashed lines) for Austria (black) and Germany (gray) during the birch pollen seasons of 2009–2013

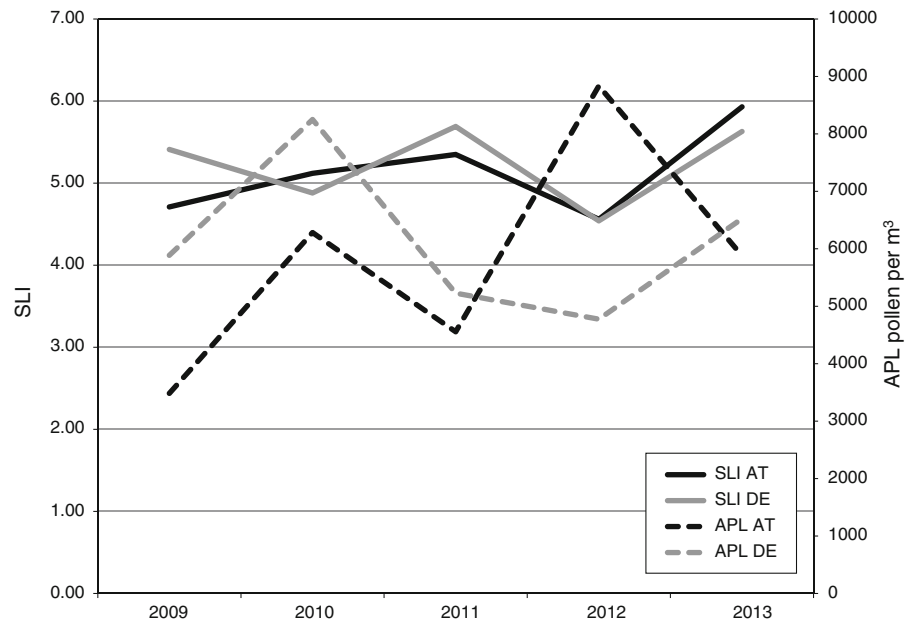
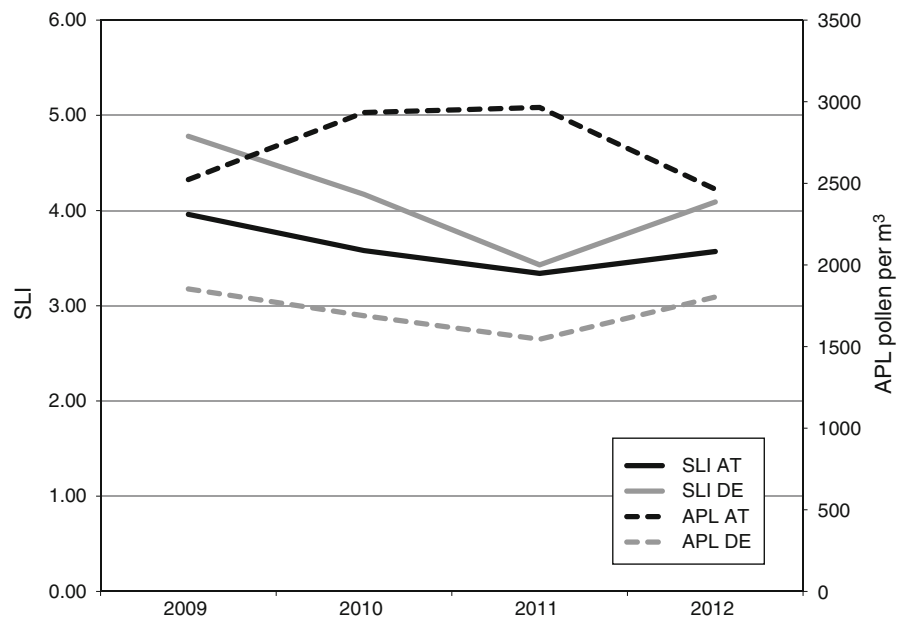


Fig. 3 SLI (continuous lines) compared to APL (dashed lines) for Austria (black) and Germany (gray) during the grass pollen seasons of 2009–2012



pollen-induced symptoms are parallel. This is observed in the case of Germany, but it is not that obvious in Austria. In the case of birch and ragweed, the relationship is not at all stable and often shows a higher SLI with lower APL.

The same regional difference seen in the grass pollen season is observed for the birch pollen season, although to a lesser extent. In Austria, the APL does not relate to the symptom data, whereas in Germany,

the SLI follows the APL from 2012 to 2013. For the ragweed pollen season, it is clear that the APL does not correlate with the SLI in either region.

4 Discussion

For the first time, the new index enables proper comparison of pollen seasons from the allergy

Fig. 4 SLI (continuous lines) compared to APL (dashed lines) for Austria (black) and Germany (gray) during the ragweed pollen seasons of 2009–2012

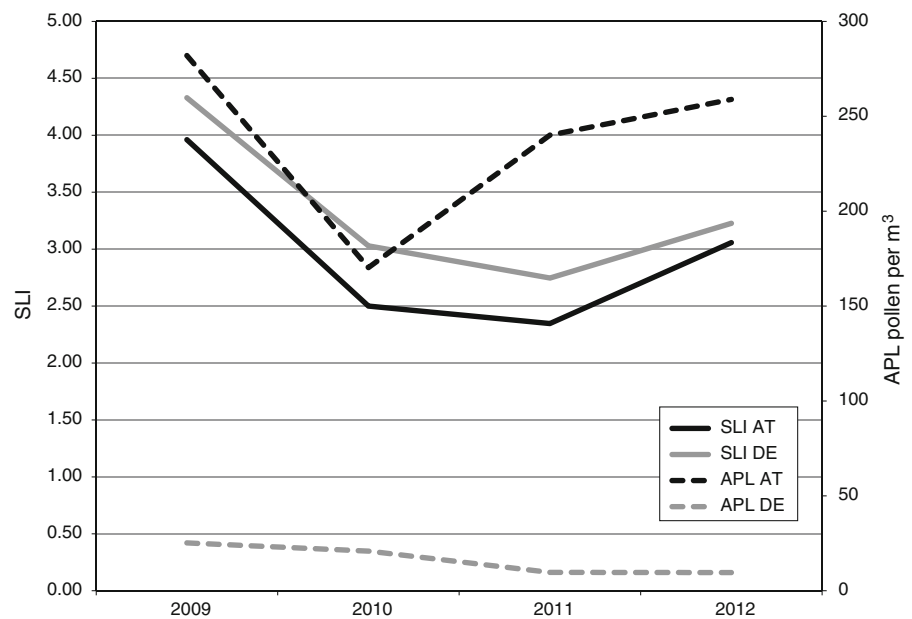
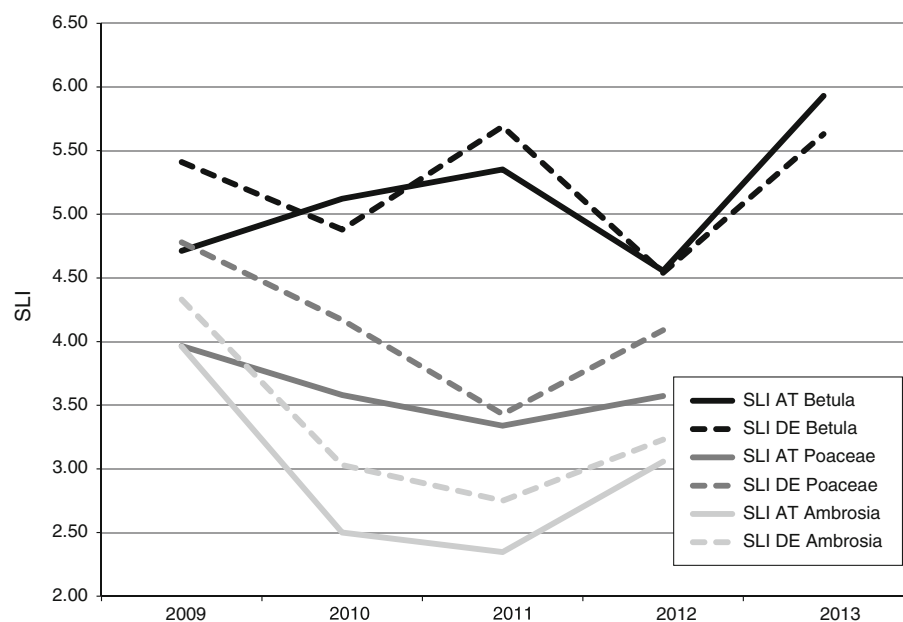


Fig. 5 SLI values for Austria (continuous lines) and Germany (dashed lines) for *Betula* (black), *Poaceae* (dark gray) and *Ambrosia* (light gray). Note the differences in the SLI levels between different pollen seasons



sufferers' point of view. A standardized procedure was developed based on the symptom data of PHD users, and pollen data for the season based on the EAN's definition. The SLI is an objective tool enabling comparison on different temporal and regional dimensions without the impact of daily pollen counts.

First and foremost, it is necessary to discuss the data presented and possible sources of misinterpretation. The majority of PHD users are not diagnosed pollen

allergy sufferers. However, since 2013, it has been possible to indicate if allergies have ever been diagnosed for a particular user and if so, which specific allergies. In future, the dataset of diagnosed users will increase and remove doubts and uncertainties concerning their data. Hitherto, users were statistically correlated to their possible allergens, giving at least some indication. Cross-reactions and the presence of other allergenic pollens could skew the results

of this study. However, there are a number of reasons considering our findings valid. The only other pollen of major importance that could interfere during the *Ambrosia* pollen season is *Artemisia*. However, the *Artemisia* pollen season overlaps with the *Ambrosia* pollen season only to a minor extent in Austria and in Germany. In Austria, the *Artemisia* pollen season usually peaks in mid-August (around the 16th of August in the last 5 years). *Ambrosia* pollen is in the air considerably later with the major loads occurring in September. In Germany, the *Artemisia* pollen season peaks at the beginning to the middle of August and is also clearly separated from the main *Ambrosia* pollination period in September. Therefore, we are confident that the symptom load calculated during the *Ambrosia* pollen seasons is tightly connected to the presence of *Ambrosia* pollen in the air.

The grass pollen season is more complicated as there are many more different pollen types that have the potential to irritate pollen allergy sufferers (e.g., *Plantago*, *Chenopodiaceae*, *Urtica* and *Mercurialis*). In this case, the high amount of data (over 84,000 entries for Austria and over 45,000 for Germany) and the high sensitization rate to grass pollen (20.2 % in Austria and 34.1 % in Germany according to Burbach et al. 2009) refer to the flowering of grasses and not to *Plantago*, *Chenopodiaceae*, *Urtica* or *Mercurialis* as the major reason for the symptom load calculated for the grass pollen season. Referring to prior knowledge, grass pollen allergy is one of the most frequent pollen allergies and in Austria the inhalation allergen most allergy sufferers are sensitized to (Hemmer et al. 2010). In additional, the results have informative value due to the size of the dataset.

Although sensitization rates to birch pollen are as high as sensitization to grass pollen in Germany (34.1 %, Burbach et al. 2009), they are lower in Austria (9.5 %, Burbach et al. 2009). The birch pollen season remains the most difficult one to interpret, because many other allergenic pollen types could overlap with the flowering of birch (for example, *Alnus*, *Corylus* or *Fraxinus*). At the moment, it is not possible to attribute symptom loads exclusively to birch pollen during the *Betula* pollen season. Nevertheless, the seasons were defined based on pollen data to ensure accurate assessment of the beginning, peak and end of the flowering of birch. Furthermore, *Alnus* and *Corylus* pollen appeared only in concentrations <20 pollen/m³ at the beginning of the birch pollen

season in the observed period (2009–2013) in both countries. Although the flowering of *Fraxinus* peaks earlier than the flowering of *Betula*, it overlaps and potentially could cause interference. Up to now, ash pollen allergy has not been known as a common problem in Austria and Germany in contrast to the situation in Switzerland (Schmid-Grendelmeier et al. 1994) and is thus not included in major sensitization rate studies (e.g., Burbach et al. 2009). Therefore, calculations of symptom loads during the ash pollen season were not included in this outline study. In future, it will be of great interest to compare the impact of ash versus birch pollen seasons. To conclude, the major part of the symptom load recorded in the PHD can be referenced to birch pollen during the birch pollen season calculated.

The amount of pollen varies regionally, and the approach adopted using large regions like Austria and Germany might seem too ambitious. This study tries to visualize the relationship between pollen counts and symptoms owing to the fact that data are not evenly gathered from all regions in the countries. The reason not to choose small regions was first to obtain a basic overview. Therefore, it was preferred to include all data accessible. Future studies should test the biogeographic distribution and variations in smaller regions. The variation in total pollen counts of all pollen monitoring stations and all years included is displayed in Table 3. It is clear that the variations in birch and grass pollens are acceptable. Ragweed pollen counts are highly variable (Table 3). We expected this variation because ragweed has not infested all parts of Germany and Austria. For example, the eastern part of Austria features high loads of *Ambrosia* pollen, whereas there is hardly any of this pollen present in the western part. Nonetheless, due to the importance of *Ambrosia* for pollen allergy sufferers and the particular time of the year of its season, it seems feasible to include it in a first study.

This paper has shown the presence of complicating variables causing an unclear relationship of APL to SLI. Such variables could be priming effects (Connell 1968) and the nonspecific prepriming phenomenon (Ellis et al. 2010), which cause a different level of symptom severity in response to the same amount of pollen type during the pollen season. However, these results are probably quite robust as they are (1) based on a large sample size (both pollen and symptom data) and (2) are consistent over several years and pollen

types. Interestingly, only Poaceae showed a somewhat strong correlation between the APL and symptom severity. This would confirm the finding of Caillaud et al. (2012) that grass pollen allergy sufferers show a linear response to grass pollen counts up to a saturation point and then plateau.

Why do pollen-induced symptoms not correlate with the APL? It is important to note that allergen versus pollen potency can be different across years and regions and that there can be interference from cross-reactivities. In the case of ragweed, the pollen season is quite free of other important aeroallergens except for mugwort. In spring, many different trees flower and the pollen seasons of different taxa overlap with that of birch. Further studies are needed to answer this question. There is also a great need to generate possible explanatory approaches that could clarify the development of tolerance to a certain amount of pollen or a particular pollen taxon in a specific region and also the different threshold levels among different populations.

However, if these results prove right, then the impact on pollen information and the scientific field is very important. Pollen season severity should be assessed with symptom data rather than with pollen data alone. Furthermore, pollen forecasts should not rely solely on pollen counts. Pollen information is vital for pollen allergy sufferers (Kiotseridis et al. 2013). The SLI has potential for application in future pollen information services. Pollen forecasts could be adjusted using symptom data to improve their accuracy. The use of symptom data seems to be a new direction toward providing improved information for pollen allergy sufferers. Furthermore, the SLI could be the basis not only for developing pollen forecasts but also for establishing symptom forecasts. The SLI is a tool that is also useful for monitoring the development of symptoms during the season and has the potential to provide new insights into the reaction of pollen allergy sufferers. However, we want to emphasize that it is not suggested that the SLI replaces pollen counts. It can though become an important additional tool for developing (personalized) pollen information and it is in this role that it should be understood.

Another possible application of the SLI in the future is to monitor the development of symptom severity in the context of climate change. The impact of climate change on the burden of allergy sufferers and the assumption of increasing severity (Cecchi et al. 2010;

Besancenot and Thibaudon 2012) can now be documented and expressed in numbers. As the APL forecast of total pollen loads is not sufficient to forecast pollen-induced symptoms, it is probably important to study the role of weather and its development, especially before the start of the pollen season, and this should be implemented to a much higher degree in forecasts. The findings of this study also have implications for the development and establishment of threshold levels (De Weger et al. 2013; COST action ES0603 n.d.). The same population shows different symptom severity in years with similar APLs, probably due to different aeroallergen versus pollen potency (Buters et al. 2012). In the light of this study, a different threshold level could be assumed not only for different regions/populations but also for different years/pollen seasons independently of the pollen count. The threshold discussion may thus start from the beginning.

5 Conclusions

The application of the SLI shows similar patterns in Austria and Germany from 2009 to 2013 and leads to the following conclusions: (1) pollen season severity based on the symptom load of PHD users is not related to the total amount of pollen; (2) PDH users react in different ways within the observed period even in seasons with comparable total pollen loads; (3) different pollen taxa have a different impact on symptoms in pollen-induced allergy, with (3a) birch pollen inducing the most severe symptoms (3b) ragweed pollen having the weakest impact and (4) regional differences in symptom loads, for example, lower grass pollen amounts inducing a higher symptom load in Germany than higher grass pollen amounts in Austria that poses the question if similar APLs can cause different SLIs. Pollen counts will remain the basis for aerobiological studies and pollen forecasts and of course pollen-induced symptoms generally follow pollen loads. This study only indicates a fact already widely accepted, namely that the same amount of pollens induce different symptom levels in different years in different regions.

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Appendix

EAN includes pollen data providers within the EAN network as listed below in alphabetical order for each country. Austria: Katharina Bastl, Ursula Brosch, Pramod Harvey, Siegfried Jäger, Maximilian Kmenta, Herta Koll, Sabine Kottik, Margit Langanger, Rudolf Litschauer, Notburga Oegg-Wahlmüller, Hanna Schantl, Jutta Schmidt, Roland Schmidt, Matt Smith, Helmut Zwander; Germany: Karl-Christian Bergmann and Stiftung Deutscher Polleninformationsdienst (PID), Polleninformationsdienst des Instituts für Meteorologie der Freien Universität Wien, Reinhard Wachter.

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