Journal of Asthma and Allergy

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

The Correlation Between Airborne Pollen and Sensitization in Children with Respiratory Allergic Diseases: A Cross-Sectional Study

Lina Xu[1,*], Yinfang Dai[1,*], Wenting Luo[2,*], Wujun Jiang[1], Qianlei Tan[1], Yanhong Lu[1], Zhifeng Huang[2], Wenjing Gu[1], Pengyun Li[1], Pengli Wang[1], Li Huang[1], Huiquan Sun[1], Chuangli Hao[1], Baoqing Sun[2]

[1]Department of Respiratory Medicine, Children's Hospital of Soochow University, Suzhou, Jiangsu, People's Republic of China; [2]Department of Allergy and Clinical Immunology, State Key Laboratory of Respiratory Disease, National Clinical Research Center for Respiratory Disease, Guangzhou Institute of Respiratory Health, First Affiliated Hospital, Guangzhou Medical University, Guangzhou, Guangdong, People's Republic of China

*These authors contributed equally to this work

Correspondence: Chuangli Hao, Department of Respiratory Medicine, Children's Hospital of Soochow University, Suzhou, 215003, People's Republic of China, Email hcl_md@sina.com; Baoqing Sun, Department of Allergy and Clinical Immunology, State Key Laboratory of Respiratory Disease, National Clinical Research Center for Respiratory Disease, Guangzhou Institute of Respiratory Health, First Affiliated Hospital, Guangzhou Medical University, Guangzhou, Guangdong, 510120, People's Republic of China, Email sunbaoqing@vip.163.com

Background: Pollen is a significant contributor to respiratory allergies worldwide, underscoring the importance of understanding its association with childhood sensitization to enhance clinical management.

Objective: This study focuses on investigating the prevalence of various airborne pollens and their correlation with clinical characteristics of childhood respiratory allergic diseases in southeastern China.

Methods: From November 2020 to October 2021, this research employed Durham monitoring samplers to collect airborne pollen. Simultaneously, skin prick tests (SPTs) were performed on children with respiratory allergic conditions at the Children's Hospital of Soochow University and standardised questionnaires are also administered to assess children's symptoms.

Results: Over the course of November 2020 to October 2021, the study identified more than 36 pollen species. Notably, the spring season (March to May) exhibited the highest pollen concentrations, with *Broussonetia* accounting for 30.04% and *Pinus* for 26.38%. Similarly, the autumn months (September to October) saw prominent taxa like *Humulus scandens* (47.55%) and Gramineae (35.93%). Among the patients, a significant 92.7% exhibited positive reactions, with 81.7% showing sensitization to house dust mites (HMD), 17.8% to pollen, and 3.7% to Cockroach. Noteworthy the five most common pollens were observed for Bermuda (6.0%), Elm pollen (6.0%), Birch pollen (4.6%), and Mugwort (4.6%). The study indicated a substantial multisensitized ratio among pollen-sensitized patients in comparison to non-pollen-sensitized ones (97.4% vs 1.6%, P <0.001). Moreover, weekly total airborne pollen concentrations showed positive correlations with weekly admissions due to allergic rhinitis(AR)(r=0.642, P <0.001), bronchial asthma (BA) (r= 0.472, P<0.001), and the coexistence of AR and BA (r=0.485, P <0.001).

Conclusion: The findings found that there were two peaks of pollen count in a year during March-May and September-October. The findings emphasize the critical role of specific airborne pollens in driving sensitization and exacerbating respiratory allergic diseases in children.

Keywords: pollen, respiratory allergic diseases, China

Key Message

In southeastern China, a region with a large population and a high prevalence of allergic diseases in children, there are indeed few studies on the relationship between respiratory allergenic diseases and airborne pollen. The aim of this study was to discuss the distribution and prevalence of airborne pollen counts in the Suzhou region of southeastern China, and also to investigate their association with pollen sensitization and respiratory allergy symptoms.

Received: 16 February 2024
Accepted: 5 December 2024
Published: 30 December 2024

Introduction

The escalating prevalence of respiratory allergic diseases over the past decades has imposed a substantial socioeconomic burden worldwide.[1,2] In China, and particularly in the southern region, respiratory allergic diseases have also become a significant public health concern.[3] Allergens, notably a significant cause of allergic rhinitis(AR) and bronchial asthma (BA), have garnered extensive attention due to their impact on public health. Common inhaled allergens encompass *Dermatophagoides* (house dust mite, HMD), pollen, mold, animal fur.[3] While research on HMD prevails in the literature, pollen-related investigations, especially in southeastern China, remain limited.[4] There's some data on AR and BA, but the pollen - allergic disease link, especially in southern China's unique climate, lacks exploration. Data on pollen's influence on these diseases is scarce. Our study on pollen aims to fill this gap for better understanding and management.

The last few decades have witnessed an increasing acknowledgment of pollen's potent allergenicity and its profound implications for human health.[5] Developed nations, especially in North America and Europe, have reported a surge in pollen-induced respiratory allergic reactions.[6] Airborne pollen monitoring, a standard practice in several countries, yields daily reports on allergenic airborne pollen and spore species during flowering seasons.[7] Gravitational methods are used. They rely on gravity to collect pollen. Specialized outdoor devices with features for pollen settling are set up. For example, collectors have surfaces good for pollen adhesion during gravity - influenced fall. This way, we can get data on pollen quantity, type, size, and shape, which is vital for understanding allergenicity and the pollen environment. Comprehensive understanding of pollen emission dynamics proves crucial for identifying potential allergens of heightened health significance across natural and inhabited regions. Considering the intricate interplay of climate, geography, and vegetation, this study assumes significance as a dedicated exploration of pollen distribution and sensitization in southeastern China.

Southeastern China, marked by affluence, abundant vegetation, and a sizable population, contends with a high prevalence of respiratory allergic diseases in children.[8,9] Paradoxically, the region lacks sufficient airborne pollen data, creating a critical void in the literature. This research thus addresses this gap, acquiring paramount importance for children afflicted with respiratory allergies. As a representative city in southeastern China, Suzhou was selected as focal point of this study.

Geographically situated in the subtropical monsoon belt, Suzhou covers 8657.3 km^2 and boasts a population exceeding 13 million in 2020. Renowned as the "Garden City", Suzhou enjoys a robust economy and a high prevalence of allergic diseases among children. Characterized by a subtropical humid monsoon climate, the city experiences an average annual temperature of 15.7°C and an annual rainfall of 1100 millimeters, fostering a diverse range of vegetation including trees, shrubs, grasses and herbs.

Despite extensive research in southeastern China to identify common inhalant allergens and elucidate the epidemiology of respiratory allergic diseases, no aerobiological data have been reported using gravitational methods. In this study, we will further analyze the aerobiological data collected using gravitational methods and provide additional data on allergic diseases, including AR and BA. This study endeavors to bridge this gap, aiming to discuss the distribution and prevalence of airborne pollen counts in Suzhou, while investigating their association with pollen sensitization and respiratory allergic symptoms in individuals.

Methods

Airborne Pollen Monitoring in the Atmosphere of Suzhou

Airborne pollen monitoring in Suzhou's atmosphere was conducted at the Children's Hospital of Soochow University, located in the central Gusu District of Suzhou, China. The Durham samplers were positioned on the hospital rooftop, approximately 18 meters above ground level. To ensure accurate data collection, the sampler was fixed on a bracket about 1.5 meters above the ground, away from tall buildings, air conditioning units, and vegetation. Trained technicians operated the samplers, which collected daily samples of airborne pollen. These samples were then examined under a microscope, and the pollen species, quantity, distribution regulation and distribution features were determined. Monthly and weekly airborne pollen concentrations were calculated based on the aggregated daily counts.

Study Population

This was a cross-sectional study. Between between November 1, 2020 and October 31, 2021, 12527 individuals with a physician-determined need for allergy testing at the Children's Hospital of Soochow University served as the study's primary data source. To be included in the study, subjects had to meet the following criteria: 1. They had a confirmed diagnosis of AR and/or BA, with and diagnostic criteria based on the Global Initiative for Asthma[10] and AR and its Impact on Asthma[11] guidelines. 2. They had resided in Suzhou for at least three years. 3. They were aged between 3 and 15 years. After exclusion, the study population consisted of 219 consecutive outpatients who were recruited.

A diagram of the procedure for including participants in the study population is shown in Figure 1.

Ethical approval for this study was obtained from the Ethics Committees of Children's Hospital of Soochow University (2018KS009). Before including any participant, we got written informed consent from parents/legal guardians using an Informed Consent Form that detailed the study's nature, purpose, risks, and benefits. They had enough time to read, understand, and ask questions. We emphasized voluntary participation and the right to withdraw without consequences.

Skin Prick Test (SPT)

SPT were meticulously executed following established protocols on the day of the clinical visit for allergy diagnosis. In line with standardized procedures, a comprehensive panel of 16 allergens from Inmunotek (Spain) was employed. This panel encompassed an array of allergens, including house dust mite (*Dermatophagoides pteronyssinus*), Cockroach, various tree species (Elm, Birch, Poplar, Willow, Platanus Hispanica, Cypress), grass (Wheat), and weed pollen (Bermuda grass, Mugwort, Timothy grass, Chenopodium album, Ragweed, Rape, Reed). Histamine diphosphate (1 mg/mL) and PBS (1 mg/mL) served as positive and negative controls, respectively, to validate the test outcomes. A qualified physician meticulously assessed the skin reactions 15 min after the application of allergens to the skin via pricking. Consistent with established international guidelines, a skin reaction was deemed positive if the mean diameter of wheal exceeded that of the negative control by 3 mm or more. In our study, allergen reactivity severity was graded

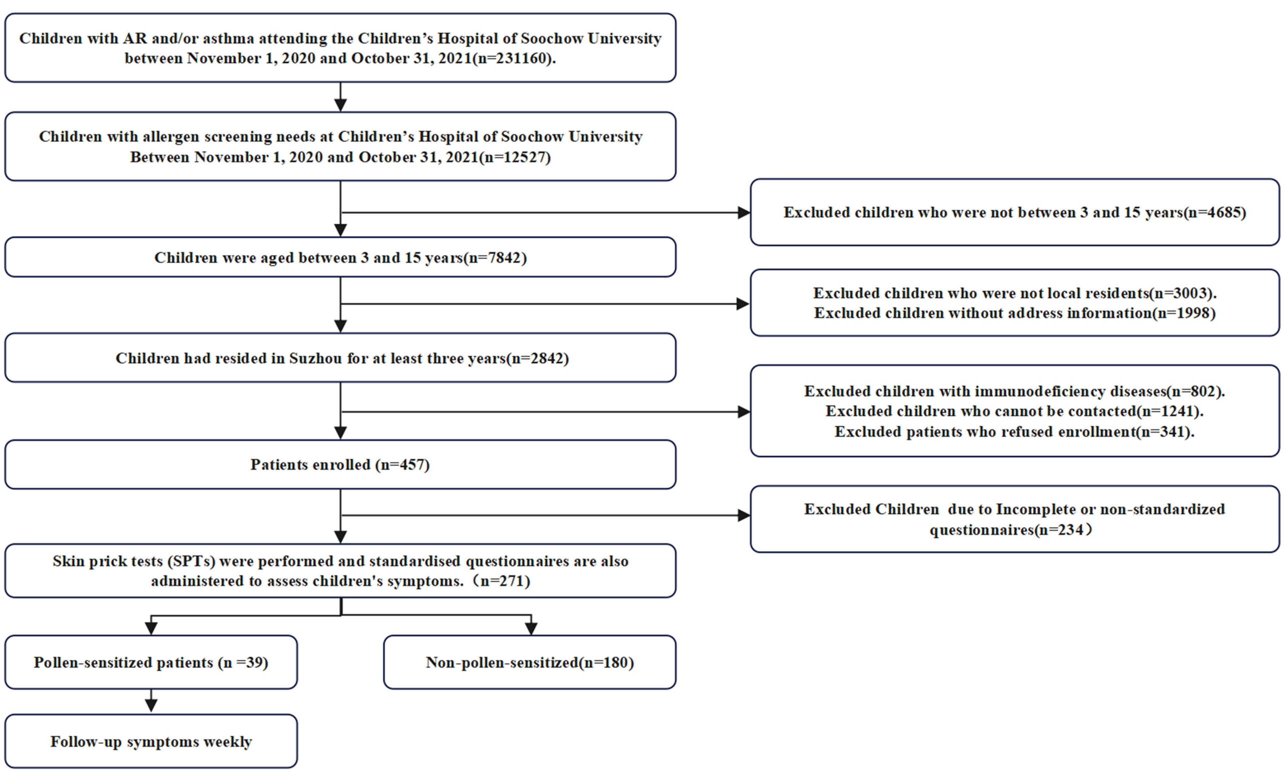

Figure 1 Flow chart for this study.

based on the criteria established in previous research.[10] Specifically, 4+ meant a wheal diameter ≥ 15 mm with significant erythema; 3+ was 10–14 mm with moderate erythema; 2+ was 5–9 mm with mild erythema; 1+ was 3–4 mm with minimal erythema.[10] This helped precisely assess allergen sensitivity. This stringent criterion ensures accurate and consistent interpretation of the skin prick test results, facilitating the identification of genuine allergic reactions.

Clinical Data

Visual Analog Scale (VAS)

This study was a prospective study. The VAS data were collected during the clinical visits of the participants. The VAS, a method recommended by the Joint Task Force on Practice Parameters, serves as a widely utilized quantitative tool for assessing the severity of symptoms. This straightforward approach aids in evaluating symptoms intensity by assigning a score ranging from 0 to 10 for various symptoms. Specifically, the physician evaluates nasal symptoms (sneezing, rhinorrhea, nasal congestion, nasal itching, and loss of sense of smell) as well as ocular symptoms (eye itching, conjunctival redness, watery eyes, and eyelid edema). Using the VAS, physicians rate the severity of each symptom on a scale from 0 to 10. A score of 0 indicates no symptoms, while a score of 10 indicates very severe symptoms.[12] This straightforward approach provides a standardized way to assess the severity of symptoms and allows for easy comparison and tracking of symptom improvement over time.

Allergic Rhinitis Control Test (ARCT)

The ARCT is a self-administrated questionnaire designed to evaluate the management of AR[13] symptoms within the preceding 2 weeks. Comprising five questions, each assigned a score ranging from 1 to 5, the individual scores are subsequently summed to yield a total score that spans from 5 (indicative of more severe symptoms) to 25 (indicative of optimal symptom control). An ARCT score of ≥20 is indicative of controlled AR, suggesting effective symptom management. Conversely, patients whose ARCT score falls below 20 are considered to have uncontrolled AR, implying that their symptom management requires further attention. Notably, the Chinese version of the ARCT has been rigorously validated, affirming its reliability and applicability within the target population. This assessment tool holds significant value in appraising the efficacy of AR management strategies and informing clinical decisions for patients with AR.

Asthma Control Test (ACT) / Childhood Asthma Control Test (C-ACT)

The ACT[14] is an instrumental tool deployed for evaluating the degree of symptom control in adolescents aged 12 to 18 years who grapple with BA. For children aged 4 to 11 years, the C-ACT comes into play.[15] This simplified self-administered questionnaire, comprising seven items, is skillfully designed to appraise the extent of BA control within this younger age group. The questionnaire is thoughtfully divided into two sections: the initial four items are tailored for children to respond to, while the concluding three items are intended to be addressed by caregivers or parents. By adeptly investigating both daytime and nighttime BA symptoms, medication usage patterns, and any resultant limitations imposed on daily activities throughout the preceding four weeks, the questionnaire provides a comprehensive assessment of BA control dynamics within the pediatric population. The C-ACT scores offer meaningful insights into the overall management and impact of BA in children. The scores derived from the C-ACT furnish clear classifications of BA control. Scores exceeding 19 were also associated with "well controlled" or "completely controlled" BA, signifying effective symptom management. Within the range of 16 to 19, scores align with "somewhat controlled" BA, indicating a moderate level of control. On the other hand, scores falling below 16 warrant the classification of "poorly controlled" or "not controlled at all" BA, highlighting the need for more intensive intervention to enhance symptom management and overall well-being. These standardized assessment tools, ACT and C-ACT, contribute invaluable insights into the effectiveness of BA management strategies, thereby empowering healthcare professionals to tailor interventions that optimize symptom control and improve the quality of life for adolescents and children affected by BA.

Emergency Hospital Admissions

In the timeframe spanning November 2020 to October 2021, an analysis was conducted on the medical records of pediatric patients who attended the outpatient and emergency department of the Children's Hospital of Soochow

University. The Hospital Information System (HIS) system was utilized to meticulously gather and organize this data. The primary objective was to identify and isolate specific subsets of patients, specifically those aged between 3 and 15 years, who had been diagnosed with either AR, BA, or a combination of both conditions. Subsequent to the data extraction process, a daily patient count was performed for each of the aforementioned diagnostic categories. Simultaneously, this dataset was correlated with corresponding daily measurements of airborne pollen concentration. Spearman's rank correlation analysis, a statistical technique suited for assessing monotonic relationships between variables, was employed to explore the potential connections between the daily patient counts and the levels of airborne pollen concentration on the same day.

Statistical Analysis

The results were represented the calculation of means, along with their respective ranges for data that exhibited a normal distribution. Frequencies, encompassing both the numerical count and the corresponding percentage of participants, were employed to portray categorical data. To establish meaningful distinctions between different groups, the chi-square test and *t*-test were utilized for comparative analysis. This facilitated an in-depth exploration of group differentials, leveraging both parametric and categorical data. Spearman correlation test, on the other hand, was employed to uncover potential relationships between symptoms and concentrations of airborne pollen. Statistical analyses were executed using the Statistical Package for the Social Sciences version 26.0, a software tool renowned for its proficiency in data analysis. A significance level of $P \le 0.05$ was adopted as the threshold, denoting statistically noteworthy outcomes.

Results

Aerobiologic Records of Pollen

Throughout the span of a year of sampling, an extensive assortment of over 36 pollen species was meticulously documented and definitively classified. A visual representation of this comprehensive dataset is vividly portrayed in Figures 1 and 2 eloquently capturing the entirety of airborne pollen records in Suzhou.

The progression of this botanical phenomenon over the course of a year revealed two prominent peaks in the distribution of airborne pollen. One zenith was observed during the spring months, spanning from March to May, while the other crescendo occurred in autumn period, spanning from September to October (Figure 2). During the vernal months, the foremost contributors to the airborne pollen panorama were the arboreal denizens (Figure 2A). Among these, the pollen of *Broussonetia* (commonly known as paper mulberry) significantly predominated, quantifying to a remarkable 1421 grains per 1000mm^2. This voluminous tally accounted for an impressive 30.04% of the total pollen corpus during the spring season. Trailing behind in prevalence were the Pinus (Pinaceae), constituting 26.38% of the overall pollen composition, and *Cinnamomum* (cinnamon), accounting for 4.54% of the total pollen amalgamation (Figures 2A and 3A).

In contrast, as autumn emerged with its unique atmospheric demeanor (from September to October), the dynamic shifted towards a prominent presence of pollen from both weeds and Gramineae family plants (Figure 2B). This

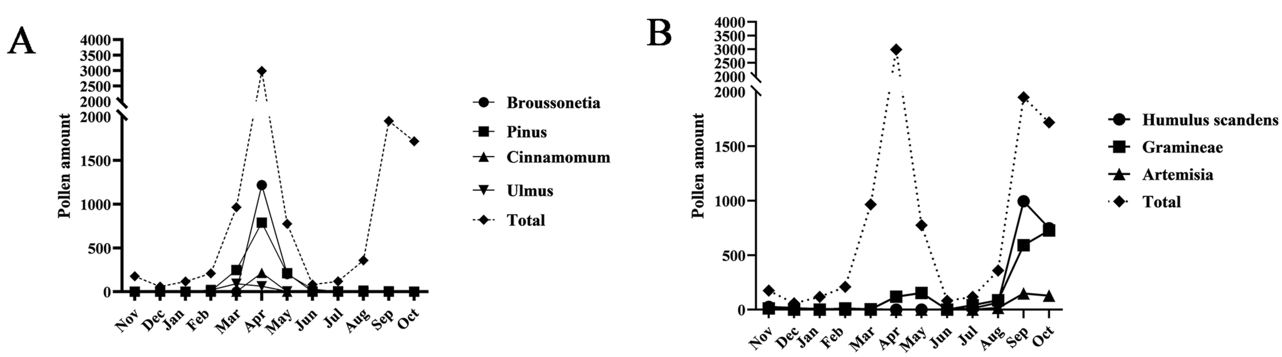

Figure 2 Monthly trend in airborne pollen concentration. (**A**) The monthly evolution of airborne pollen concentration originating from key tree pollen types, namely *Broussonetia*, *Pinus*, *Cinnamomum*, Ulmus, alongside the comprehensive total pollen count. (**B**) The monthly progression of airborne pollen concentration sourced from prominent weed pollen variants including Humulus scandens, Artemisia, as well as Gramineae (glasswort). The inclusive total pollen concentration is also highlighted.

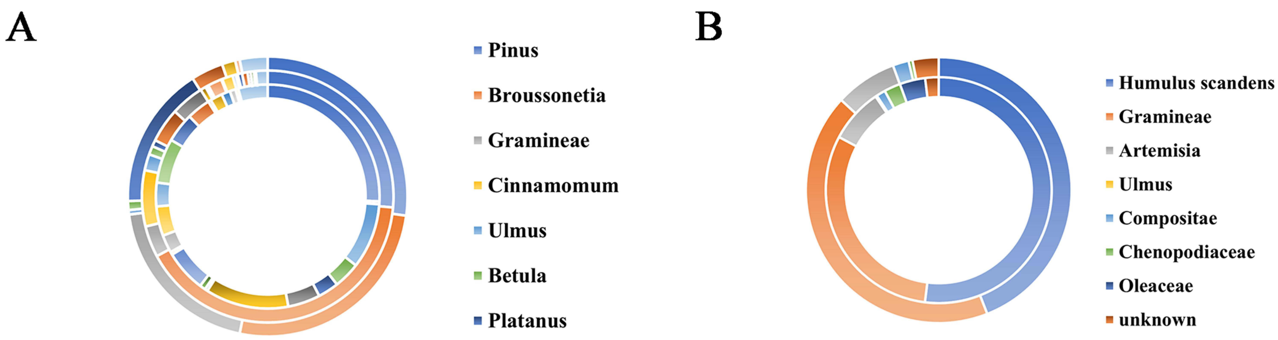

Figure 3 Ring diagram traces airborne presence. (**A**) A ring structure to visually represent the proportional airborne pollen presence in Suzhou across the months of March, April, and May. The innermost circle provides insights into pollen distribution during March, the middle circle illustrates the distribution for April, and the outermost circle showcases the distribution during May. (**B**) The relative proportion of airborne pollen presence in Suzhou during the months of September and October. The innermost circle reflects the distribution for September, while the outermost circle highlights the distribution observed in October.

captivating tableau of airborne pollen was chiefly characterized by the prevalence of certain taxa. *Humulus scandens* (Japanese hop) reigned supreme, contributing a substantial 47.55% of the pollen consortium, closely followed by Gramineae at 35.93%, and *Artemisia* (mugwort) at 7.55% during the autumn months (Figures 2B and 3B).

Demographic Variables of Patients

After exclusion, the study population consisted of 219 consecutive outpatients who were recruited. Of the enrolled participants, 80 (36.5%) were females, and 139 (63.5%) were males, and their median age was 7.09±3.07 years. Based on their age, the patients were categorized into two distinct groups: the 3–6 years age group (n = 110) and 7–15 years age group (n = 109). Among the participants, 51 patients with AR only, 31 patients with BA only, and 137 patients with AR and BA. In addition, the patients were stratified into two subgroups: pollen-sensitized (n=39) and non-pollen-sensitized (n=180) depending on their sensitization to pollen extracts. There were no statistically significant disparities observed between the two groups in terms of sex, mode of delivery, family history, complications, and the rhinitis symptom score (ARCT score), with all *P* values exceeding 0.05 (Table 1).

To delineate the distinctions between the pollen-sensitized and non-pollen-sensitized cohorts, it was found that in the age group of 7–14 years, the pollen-sensitized group exhibited higher representation compared to the non-pollen-sensitized group

Table 1 Demographic Variables of Patients

Demographic Variable	Pollen-Sensitized Patients (n =39)	Non-Pollen-Sensitized (n=180)		P
Age n (%)				
3–6y	11 (28.2%)	99 (55.0%)	9.206	0.002*
>6y	28 (71.8%)	81 (35.0%)		
Sex n (%)				
Male	28(71.8%)	69(38.3%)	1.418	0.234
Female	11(28.2%)	111(61.7%)		
Mode of delivery n (%)				
Normal delivery	23(59.0%)	92(51.1%)	0.795	0.073
Cesarean section	16(41.0%)	88(48.9%)		

(*Continued*)

Table 1 (Continued).

Demographic Variable	**Pollen-Sensitized Patients (n =39)**	**Non-Pollen-Sensitized (n=180)**		**P**
Family history n (%)				
No	9(23.1%)	62(34.4%)	1.891	0.169
Yes	30(76.9%)	118(65.6%)		
Diseases n (%)				
Allergy rhinitis	6(15.4%)	45(25.0%)	11.6	0.003*
Bronchial asthma	0(0%)	31(17.2%)		
Allergy rhinitis with bronchial asthma	33(84.6%)	104(57.8%)		
Clinical implications n (%)				
Eczema	10(25.6%)	45(25.0%)	0.007	0.933
Urticaria	11(28.2%)	30(16.7%)	2.805	0.094
Food allergy	3(7.7%)	10(5.6%)	0.262	0.609
Allergic conjunctivitis	15(38.5%)	71(39.4%)	0.013	0.909
Pattern of sensitized n (%)				
Monosensitized	1(2.6%)	127(98.4%)	151.75	<0.001*
Multisensitized	38(97.4%)†	2(1.6%)		
ARCT score (mean ±SD)	18±3.4	18±3.7	0.762	0.447
ACT/C-ACT score (mean ±SD)	21±2.4	20±2.3	0.903	0.323

Notes: †: Among the 39 pollen - sensitized patients, 29 (74.4%) were found to be multisensitized with HDM. *P < 0.05.

(71.8% vs 35.0%, *P* = 0.002). Furthermore, a greater prevalence of AR coupled with BA was observed in the pollen-sensitized group in comparison to the non-pollen-sensitized group (84.6% vs 57.8%, *P* = 0.004). Conversely, the ratio of multi-sensitization was notably higher among pollen-sensitized patients as opposed to non-pollen-sensitized patients (97.4% vs 1.6%, *P* <0.001), signifying a pronounced divergence in this aspect between the two groups (Table 1).

Detection of Skin Allergic Sensitization to Pollen

Within this patient cohort, 203 patients (92.7%) exhibited positive reactions in their SPT. Specifically, 161 patients (81.7%) demonstrated positive sensitization to HMD, while 39 (17.8%) showed positive reactions to pollen, and 8 (3.7%) to Cockroach allergens. The severity of allergen reactivity was categorized into strong positive reactions (3+ ~ 4+) and weak positive reactions (2+ ~ 1+). Notably, a substantial 129 cases (58.9%) displayed a robust positive response to HDM, whereas 3 cases (1.4%) exhibited a pronounced positive reaction to Chenopodium album.

Turning to the SPT outcome for airborne pollens, the results were as follows: Bermuda and Elm pollen each accounted for 6.0% of cases, Birch pollen contributed to 4.6%, Mugwort and poplar pollen yielded 4.6% and 3.2% cases, respectively. Further insight into the frequencies and percentages of positive skin reactions for all studied pollen allergens is summarized in Figure 4.

It is noteworthy that although pollen counts were documented on daily basis, this analysis reports the total weekly mean pollen count. Remarkably, weekly aggregate airborne pollen concentrations exhibited significant positive correlations with weekly attendance rates (both outpatient and emergency department) for AR (*r*=0.642, *P*<0.001), BA

https://doi.org/10.2147/JAA.S464444

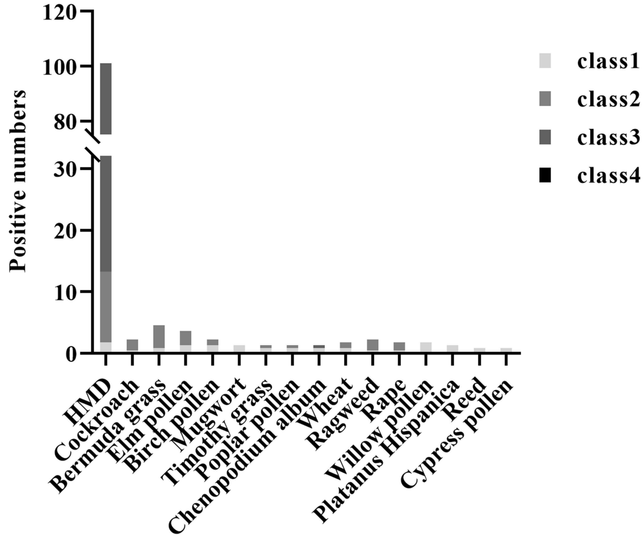

Figure 4 The frequency of SPT positivity to various aeroallergens.

(*r*=0.472, *P*<0.001), and concurrent rhinitis with BA (r=0.485, *P*<0.001). Of these, weeds and grass pollen types (*Humulus scandens*, Poaceae, *Artemisia*) was strongly associated with outpatient and emergency department visits (Figure 5A). Conversely, the correlations between attendance rates and tree airborne pollen concentration did not yield statistically significant results (*P*<0.05) (Figure 5B).

Correlation Between AR/BA Symptoms and Pollen Counts

Although pollen counts were conducted on a daily basis using microscopy, this manuscript presents the findings based on a comprehensive total monthly mean pollen count throughout all analysis. To ascertain potential correlations, Spearman correlation tests were employed to examine the correlation between pollen-sensitized patients' symptom levels, and pollen counts measured simultaneously. As depicted in Figure 6, significant and positive correlations emerged between pollen count levels and the symptom scores for AR. This was particularly pronounced in relation to specific nasal symptoms such as sneezing, rhinorrhea, nasal congestion, and nasal itching, along with ocular symptom including conjunctival redness. Furthermore, a discernible yet weak positive correlation was observed between the total monthly mean pollen count and ACT/C-ACT score for BA (*r* = 0.297, *P* = 0.034).

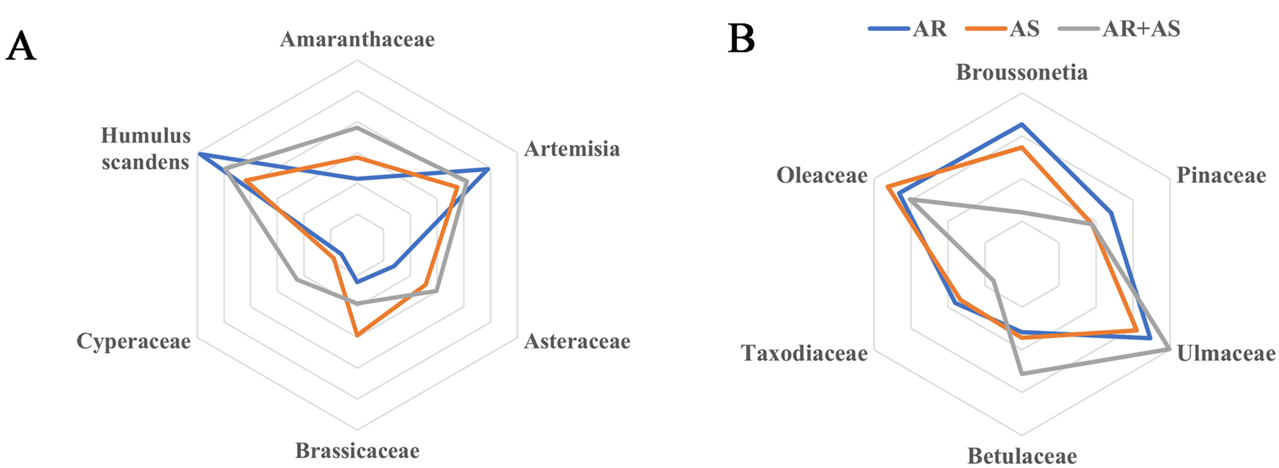

Figure 5 Correlation coefficients (r) were calculated to quantify the relationship between the weekly mean pollen count (measured in pollen grains per square meter) and the weekly outpatient visits for respiratory allergic diseases. (**A**) The correlation between grass and weeds pollen concentrations and the weekly number of admissions for respiratory allergic diseases. (**B**) The correlation between tree pollen concentrations and the weekly count of admissions for respiratory allergic diseases.

 https://doi.org/10.2147/JAA.S464444

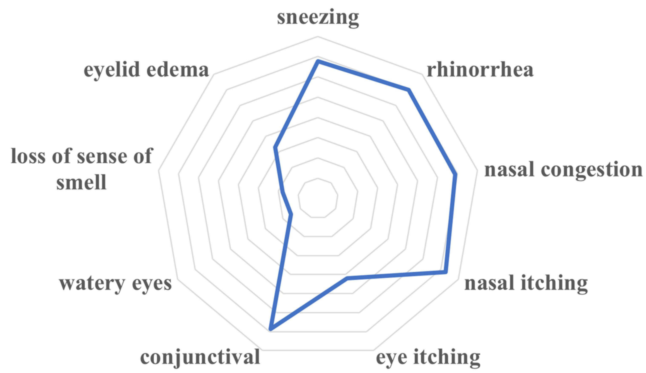

Figure 6 The Relationship between Airborne Pollen Content and VAS Score in Children with Allergic Rhinitis (AR). A score of 0 indicates no symptoms, and a score of 10 represents very severe symptoms. The higher the score, the more severe the symptoms.

Discussion

Our research highlights a distinct pattern in the distribution of airborne pollen across the Suzhou region, characterized by two notable peaks during spring and autumn. The primary peak spans from March to May, with a smaller peak observed in September and October. Notably, a surge in patient visits seeking treatment for AR aligns with elevated pollen concentrations. Remarkably, a robust correlation is discerned between the pollen concentration and nasal symptoms experienced by rhinitis patients, whereas a comparatively weaker correlation is observed between pollen concentration and BA symptoms among patients with BA.

Concentrations of Airborne Pollen

A comprehensive survey yielded a total of 36 pollen genera under examination. Distinct seasonal emerged, marked by two prominent peaks: March to May during the spring season and September to October in autumn. Notably, pollen concentrations in spring were observed to exceed those in autumn. During spring, tree species emerged as the principal contributors to pollen counts, including *Broussonetia* (Mulberry), *Pinus*, *Cinnamomum*, among others. Conversely, autumnal pollens counts were primarily sourced from weeds and grasses such as *Humulus scandens*, Gramineae, *Artemisia*, and more. These findings closely parallel those documented in neighboring cities boasting similar climatic conditions.[16,17] The prevalence of *Broussonetia*, *Pinus*, *Cinnamomum* as prevalent greening plants, extensively cultivated as street trees in Suzhou, accounts for their pronounced representation.

This investigation illuminates mulberry pollen's preeminent role as the most prevalent aeroallergen within the Suzhou region. The historical significance of Suzhou as a vital silk-producing area has perpetuated the widespread cultivation of mulberry trees, essential as a food source for silkworms in silk production.[18] As a result, the presence of mulberry trees has become deeply entrenched in the landscape of the Suzhou region. Pollen concentrations were consistent with plant cultivation. This study suggests that we should pay attention to health protection along with economic development.

The Prevalence of Positive SPT Results

In line with findings from other studies, the outcomes of the skin prick tests reveal a prevailing trend of sensitization among patients with respiratory allergic conditions, primarily directed towards HDM allergens. Notably, Bermuda, Elm pollen, and birch pollen emerged as the top three sensitized pollen allergens driving sensitization, as evidenced by the SPT. However, sensitization rates to airborne pollen among children were extremely low. These results echo similar trends documented in southeastern China,[19] which stand in contrast to higher rates reported in populations from northern China, Europe,[20] and the United States. Curiously, despite Suzhou's substantial vegetation coverage, the sensitization rate to pollen allergens remains comparably low. This may be attributed to the unique climate conditions characterizing Suzhou. With an annual precipitation exceeding 1000 mm and elevated humidity levels, the environment in Suzhou is less conducive to the widespread dissemination of pollen in the air. This contrastingly damp and moist climate could potentially inhibit the propagation of airborne pollen, thus contributing to the observed reduced sensitization rates in the population.

Correlation Between Pollen Concentrations and Number of Clinic Visits

Pollen concentration levels are widely acknowledged for their capacity to influence allergy symptoms.[21] This study distinctly illustrates that weekly total airborne pollen concentrations, specifically pertaining to two weeds and grass pollen types under investigation (Humulus scandens, Poaceae, Artemisia), are significantly and positively correlated with the weekly admissions (both outpatient and emergency department) of patients with AR. Conversely, no significant correlation was observed between pollen concentrations originating from trees and the admission rates.

This observed pattern aligns with analogous findings reported in other countries. For instance, in Kuwait, the correlation between the number of new AR patients and weeds pollen was strikingly significant (r=0.75, P<0.001), whereas grass and trees pollens displayed no such correlation.[22] Similarly, in India, while the monthly count of grass pollens exhibited a notable correlation with new patient numbers, such correlations were absent for both trees and weeds. These international studies collectively suggest that the patient influx in various regions is influenced by distinct pollen types, possibly related to specific sensitizing pollen varieties endemic to each region.

In the Suzhou region, a notable contrast emerges with extremely low sensitization rates to airborne pollen despite a significant number of AR patients. Considering the diagnostic context of AR, it becomes apparent that the Suzhou area potentially presents attributes characteristic of Local allergic rhinitis (LAR). LAR, a recently identified chronic rhinitis phenotype, involves patients with chronic nasal symptoms suggestive of allergy. Such individuals exhibit a unique pattern characterized by negative of SPT and serum specific IgE responses to relevant aeroallergens, ye test positively in the nasal allergen challenge (NAC). This implies a need for further substantiation through NAC procedures.

Interestingly, our skin tests with pollen allergens indicated minimal or no reactivity. This infers that pollen might not serve as a significant allergen for our region. However, given the high prevalence of HDM sensitization, it is possible that HDM is masking the true impact of pollen on allergic symptoms and disease severity. The intricate interplay of factors influences both pollen concentration and sensitization rates. Research by Bartková-Ščevkova highlighted a negative correlation between atmospheric pollen levels and relative humidity, particularly in Bratislava, Slovakia.[23] Authors, including Bartková-Ščevkova, underscored the pronounced negative correlation with rainfall, particularly in cases of prolonged (days or months) or intense rainfall in specific regions. Suzhou, situated within a subtropical monsoon climate characterized by ample rainfall and high relative humidity, fosters conditions conducive to pollen settlement while minimizing airborne dispersion. Consequently, inhaled allergens in Suzhou, dominated by dust mites, exhibit low pollen sensitization rates, reminiscent of previous surveys in China's southeastern coastal areas.

The Severity of the Disease

Local pollen counts are widely recognized as a pivotal indicator of pollen exposure, holding particular importance across various global regions. Notably, during the pollen dispersal season, heightened pollen exposure levels can significantly impact the severity of allergic conditions. The data gleaned from this study effectively underscored a substantial correlation between pollen counts and symptoms associated with AR. Specifically, pollen concentrations exhibited a notably stronger correlation with nasal symptoms, while the connection with ocular symptoms was comparatively weaker. This pattern can potentially be attributed to the nasal-ocular reflex,[24] a mechanism implicated in the manifestation of ocular symptoms linked to AR. Existing research has indicated that nearly 40% of patients with AR experience ocular symptoms, with allergen exposure triggering conjunctival allergic reactions through direct contact and eliciting ocular symptoms via the nasal-ocular reflex,[25] due to allergen irritation in the nasal passages. Consequently, allergens are more predisposed to incite nasal symptoms than ocular manifestations. Further substantiating prior findings, this study concurred with previous study, highlighting that pollen concentration indeed correlates with BA symptoms. This alignment with existing knowledge reinforces the impact of heightened pollen exposure, particularly during periods of elevated pollen levels, and its potential influence on the severity of respiratory conditions. It becomes evident that establishing a pollen exposure threshold — encompassing factors such as pollen type and its individual or mixed nature —becomes pivotal for effective respiratory disease prevention strategies.

In the pursuit of enhancing disease management, elevating patient satisfaction, and optimizing preventive measures, a comprehensive understanding of allergic individuals' symptoms becomes imperative. This includes discerning the sensitization patterns and the unique characteristics of the disease. Such insights would significantly contribute to refining disease control strategies and amplifying the efficacy of preventive interventions. Given the potential confounding effect of HDM sensitization on disease severity, future studies should investigate the combined impact of HDM and pollen on the severity of allergic diseases.

Limitations

An acknowledged limitation of our study lies in its one-year duration. Furthermore, our investigation did not encompass the assessment of aeroallergens beyond the designated. We also refrained from exploring the potential impacts of diverse meteorological events, including storms, and their known capacity to elevate allergen levels. Importantly, the lack of detailed HDM information and its interactions with pollen is a significant shortcoming, crucial for developing better predictive models and strategies for respiratory allergic diseases in children.

Future work will entail conducting long-term pollen concentration surveys to understand annual variations. We will collect weather data to explore relationships between pollen, climate, and pollutants. Also, we will focus on patients positive for pollen and negative for HDM allergens at admission to exclude HDM interference. Nasal provocation tests will be used to clarify the AR - LAR relationship, enhancing our understanding of respiratory allergic diseases in children and aiding in more accurate diagnoses and personalized treatments.

Conclusions

Broussonetia pollen and Pinaceae pollen stand out as the primary pollen contributors, while Humulus pollen and Poaceae pollen take the lead during autumn. The airborne pollen distribution in Suzhou exhibits two prominent peaks—spring and autumn. Notably, only a minority of children with respiratory allergic conditions appear to have a connection with airborne pollens in Suzhou. Furthermore, pollen concentration correlates with AR severity and cases, but this requires further exploration considering HDM and refined methods.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. Data is available from the corresponding author, Hao Chuangli, at the Children's Hospital of Soochow University.

Ethics Approval

This study was approved by of the Ethics Committee, Children's Hospital of Soochow University (reference number: No. 93 of 2018) and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants or their parents/legal guardians for those under 18 years prior to their inclusion in the study.

Acknowledgments

We thank all of the families that took part in the study and made possible this research.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study was supported by the Guangzhou Science and Technology Foundation (2023A03J0365), Guangdong Zhong Nanshan Medical Foundation (20220081); Jiangsu Province key medical discipline construction institution (JSDW202204); Suzhou Science Education and Health Program (KJXW2023027); New Clinical Diagnosis and Treatment Technology and Public Health Project (SKY2022051); Suzhou Applied Basic Research Project (SYW2024099).

Disclosure

There are no competing interests.

References

1. Asher MI, Montefort S, Bjorksten B, et al. Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and eczema in childhood: ISAAC phases one and three repeat multicountry cross-sectional surveys. *Lancet*. 2006;368(9537):733–743. doi:10.1016/S0140-6736(06)69283-0
2. Zuberbier T, Lotvall J, Simoens S, Subramanian SV, Church MK. Economic burden of inadequate management of allergic diseases in the European Union: a GA(2) LEN review. *Allergy*. 2014;69(10):1275–1279. doi:10.1111/all.12470
3. Luo W, Wang D, Zhang T, et al. Prevalence patterns of allergen sensitization by region, gender, age, and season among patients with allergic symptoms in mainland China: a four-year multicenter study. *Allergy*. 2021;76(2):589–593. doi:10.1111/all.14597
4. Hu H, Huang H, Liao C, et al. A study of allergen detection panel in Guangzhou, southern China based on real-world data from the past 7 years. *Sci Rep*. 2023;13(1):14855. doi:10.1038/s41598-023-41949-x
5. de Weger LA, Bergmann KC, Rantio-Lehtimäki A, et al. Impact of Pollen. *Allergenic pollen*. 2012;161–215.
6. Datema MR, Zuidmeer-Jongejan L, Asero R, et al. Hazelnut allergy across Europe dissected molecularly: a EuroPrevall outpatient clinic survey. *J Allergy Clin Immunol*. 2015;136(2):382–391. doi:10.1016/j.jaci.2014.12.1949
7. Garcia-Mozo H, Yaezel L, Oteros J, Galan C. Statistical approach to the analysis of olive long-term pollen season trends in southern Spain. *Sci Total Environ*. 2014;473–474:103–109. doi:10.1016/j.scitotenv.2013.11.142
8. Tang SP, Liu YL, Wang SB, et al. Trends in prevalence and risk factors of childhood asthma in Fuzhou, a city in Southeastern China. *J Asthma*. 2015;52(1):10–15. doi:10.3109/02770903.2014.952434
9. Zhang Y, Zhang L. Increasing prevalence of allergic rhinitis in China. *Allergy Asthma Immunol Res*. 2019;11(2):156–169. doi:10.4168/aair.2019.11.2.156
10. Bateman ED, Hurd SS, Barnes PJ, et al. Global strategy for asthma management and prevention: GINA executive summary. *Eur Respir J*. 2008;31(1):143–178. doi:10.1183/09031936.00138707
11. Brozek JL, Bousquet J, Agache I, et al. Allergic rhinitis and its impact on asthma (ARIA) guidelines-2016 revision. *J Allergy Clin Immunol*. 2017;140(4):950–958. doi:10.1016/j.jaci.2017.03.050
12. Del CA, Santos V, Montoro J, et al. Allergic rhinitis severity can be assessed using a visual analogue scale in mild, moderate and severe. *Rhinology*. 2017;55(1):34–38. doi:10.4193/Rhin16.025
13. Demoly P, Jankowski R, Chassany O, Bessah Y, Allaert FA. Validation of a self-questionnaire for assessing the control of allergic rhinitis. *Clin Exp Allergy*. 2011;41(6):860–868. doi:10.1111/j.1365-2222.2011.03734.x
14. Nathan RA, Sorkness CA, Kosinski M, et al. Development of the asthma control test: a survey for assessing asthma control. *J Allergy Clin Immunol*. 2004;113(1):59–65. doi:10.1016/j.jaci.2003.09.008
15. Liu AH, Zeiger R, Sorkness C, et al. Development and cross-sectional validation of the Childhood Asthma Control Test. *J Allergy Clin Immunol*. 2007;119(4):817–825. doi:10.1016/j.jaci.2006.12.662
16. Bishan C, Bing L, Chixin C, et al. Relationship between airborne pollen assemblages and major meteorological parameters in Zhanjiang, South China. *PLoS One*. 2020;15(10):e0240160. doi:10.1371/journal.pone.0240160
17. Sun L, Xu Y, Wang Y, et al. Species and quantity of airborne pollens in Shanghai as monitored by gravitational and volumetric methods. *Asian Pac J Allergy Immunol*. 2017;35(1):38–45. doi:10.12932/AP0743
18. Ma Y, Han TT, Zhang P, et al. Occurrence and pathogenicity of hop stunt viroid infecting mulberry (Morus alba) plants in China. *Plant Dis*. 2023;107(10):2971–2977. doi:10.1094/PDIS-08-22-1865-RE
19. Wu L, Luo W, Hu H, et al. A multicenter study assessing risk factors and aeroallergens sensitization characteristics in children with self-reported allergic rhinitis in China. *J Asthma Allergy*. 2021;14:1453–1462. doi:10.2147/JAA.S342495
20. Burbach GJ, Heinzerling LM, Edenharter G, et al. GA(2)LEN skin test study II: clinical relevance of inhalant allergen sensitizations in Europe. *Allergy*. 2009;64(10):1507–1515. doi:10.1111/j.1398-9995.2009.02089.x
21. Hoffmann TM, Travaglini A, Brighetti MA, et al. Cumulative pollen concentration curves for pollen allergy diagnosis. *J Investig Allergol Clin Immunol*. 2021;31(4):340–343. doi:10.18176/jiaci.0646
22. Behbehani N, Arifhodzic N, Al-Mousawi M, et al. The seasonal variation in allergic rhinitis and its correlation with outdoor allergens in Kuwait. *Int Arch Allergy Immunol*. 2004;133(2):164–167. doi:10.1159/000076622
23. Bartkova-Scevkova J. The influence of temperature, relative humidity and rainfall on the occurrence of pollen allergens (Betula, Poaceae, Ambrosia artemisiifolia) in the atmosphere of Bratislava (Slovakia). *Int J Biometeorol*. 2003;48(1):1–5. doi:10.1007/s00484-003-0166-2
24. Naclerio RM, Pinto J, DeTineo M, Baroody FM. Elucidating the mechanism underlying the ocular symptoms associated with allergic rhinitis. *Allergy Asthma Proc*. 2008;29(1):24–28. doi:10.2500/aap2008.29.3075
25. Baroody FM, Foster KA, Markaryan A, DeTineo M, Naclerio RM. Nasal ocular reflexes and eye symptoms in patients with allergic rhinitis. *Ann Allergy Asthma Immunol*. 2008;100(3):194–199. doi:10.1016/S1081-1206(10)60442-5