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A novel experimental technology for testing efficacy of air purifiers on pollen reduction

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Abstract

Background Allergenic pollen exposure is mostly seen as an outdoor phenomenon but studies have shown an indoor exposure: different pollen species including birch and grass pollen in houses, schools, and shops are leading to long-lasting symptoms even after the pollen season because pollen settle on surfaces and re-enter the indoor air depending on ventilation. To reduce indoor pollen load, windows need to be closed and devices should be used: as pure wiping and cleaning of surfaces is mostly not sufficient, air cleaners may be helpful in reducing pollen counts in indoor environment.

Objective The efficacy of an air cleaner is usually described by the filtration rate of standard dust particle sizes which is not necessarily related to clinical efficacy.

Methods A novel study design was developed using the technical equipment of a new mobile exposure chamber to investigate participants with allergic rhinitis (individual observational, controlled, prospective, single arm study).

Results The tested air cleaner reduced the grass pollen-induced (4000 grass pollen/m³ over 90 min) nasal symptoms (total nasal symptom score) significantly from 6 and 4 points (1st and 2nd exposure in sham run) to less than 1 point when air cleaner was activated.

Conclusions The novel study protocol is suitable for testing efficacy of air cleaners and the tested air

cleaner is effective in reducing clinical symptoms due to grass pollen in an indoor environment.

Keywords Air purifier · Efficacy · Pollen in-door exposure · Mobile exposure chamber · Allergic rhinitis

Abbreviations

FEV1	Forced expiratory volume in 1 s
PEF	Peak expiratory flow
PNIF	Peak nasal inspiratory flow
TNSS	Total nasal symptom score
TSS	Total symptom score

Introduction

Allergenic pollen are the most important and most frequent trigger for allergic diseases [1]. In the German adult population, pollen-induced allergies are an enormous public health issue with a prevalence of 14.8% physician-diagnosed hay-fever and 8.6% asthma [2, 3]. Asthma and hay-fever lead to missed school or working days, demand from families to manage asthma care for their children, and increase health care costs [4]. Since Europeans spend about 70% of their time at home, reducing exposures to allergy and asthma triggers in residential settings is an important goal in treating allergic patients.

Pollen exposure is mostly seen as an outdoor exposure but studies have shown the presence of different pollen species including birch and grass pollen in houses, schools, and shops [5–7] leading to long-lasting symptoms even after the pollen season [8].

The objective of the study was to determine the efficacy of a readily available air purifier in removing airborne grass pollen with the aim of preventing nasal allergy symptoms in persons with grass pollen-induced allergic rhinoconjunctivitis. Grass pollen were chosen

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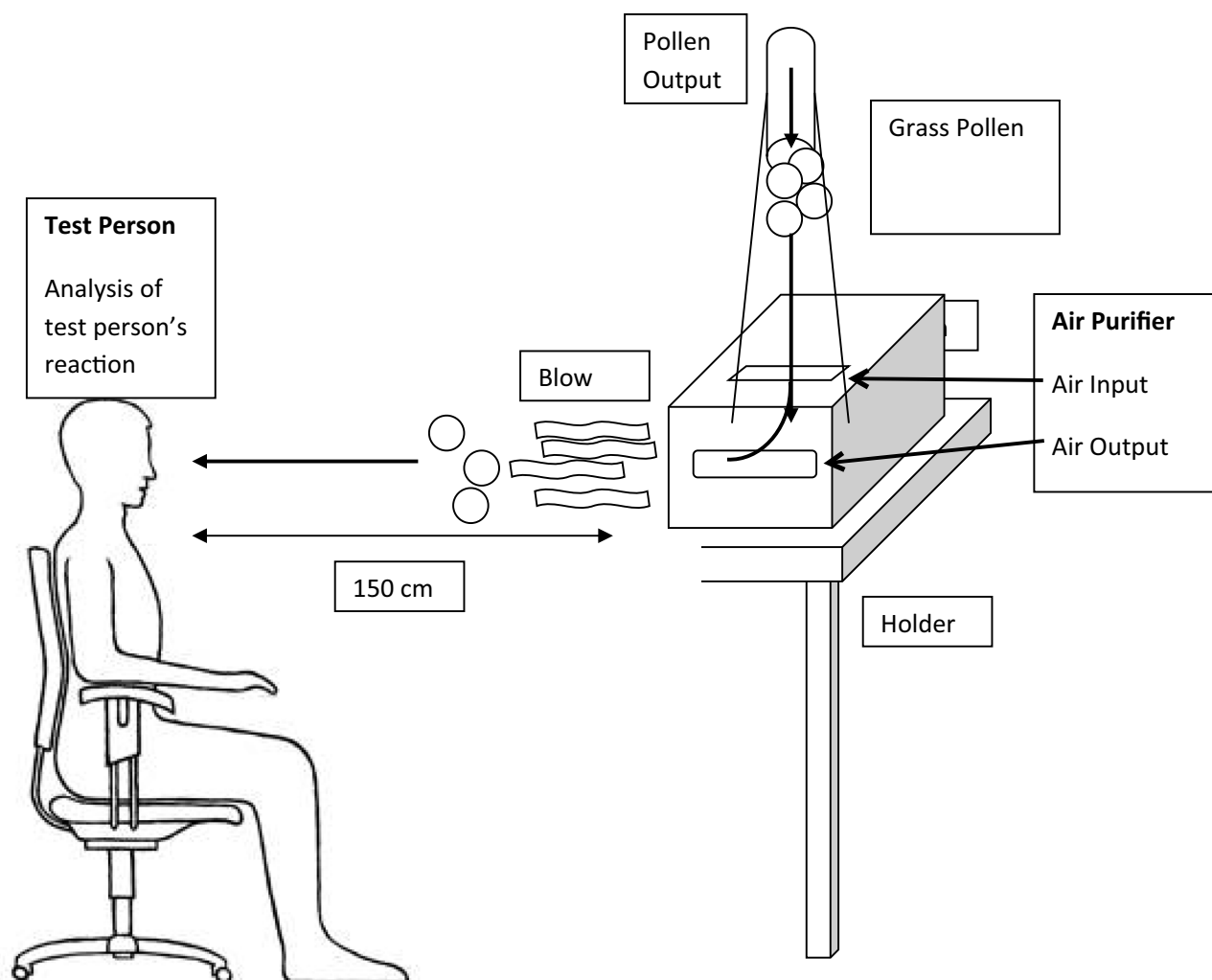


Fig. 1 Study design in the mobile pollen chamber

due to the fact that they are globally present and have a very high prevalence of sensitization [9].

Material and methods

Study design

In September 2015, a Philips AC4012 Air Purifier was used in an individual observational (in-use observation), controlled, prospective, single arm study.

Exposure

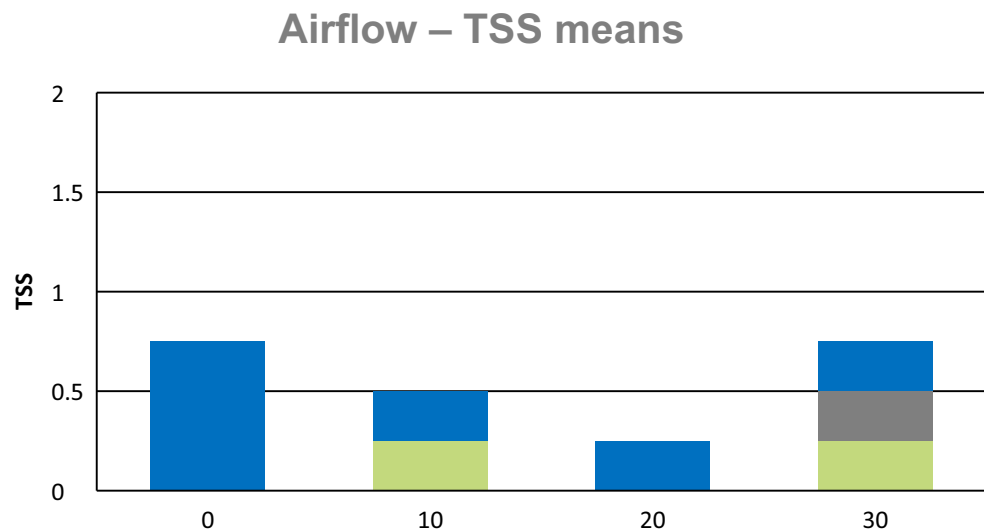
The air cleaner efficacy was investigated in a mobile exposure chamber (www.mcxperts.com), which is technically designed to ensure standardized allergen exposure of each individual participant [10]. It has undergone a comprehensive clinical evaluation for exposures to grass and birch pollen [11]. Tests were done in three steps.

1. Testing the potential influence of the active air purifier (and its airflow at the outlet) on triggering symptoms.

The participants sat in the pollen chamber at a distance of 150 cm from the outlet of the air purifier, which was equipped with a filter. No pollen was released. The participants were solely exposed to inside air and airflow from the air purifier. This distance was maintained for all further tests with pollen and the outlet of the air purifier with and without the filter.

2. Pollen exposure without filter in the air purifier (sham run): participants were exposed twice on two different days to a concentration of 4000 grass pollen/m³ air per 90-minute observation period. Comparative measurements proved that the selected concentration triggers a score of about 6 points on the symptom severity scale. The grass pollen were released through the air purifier device without the filter cartridge in place (Fig. 1).

Fig. 2 Overview of the Total Symptom Score (TSS, mean values) before and after 10, 20 and 30 min. In four subjects with allergic rhinitis without medication who were exposed to the airflow from the outlet of the tested air purifier at a distance of 1.5 m



To connect the pollen outlet in the chamber's ceiling to the inlet of the air purifier, it was placed under the pollen outlet with the air inlet facing the pollen outlet. Due to the suction of the machine, no other connection was needed to direct the full amount of pollen through the air purifier. The functioning of the setup was measured with a laser particle counter. The air outlet was directed in a horizontal position towards the participants. During exposure, two participants were in the pollen chamber.

3. Pollen exposure with filter in the air purifier: participants were exposed twice on two different days to a concentration of 4000 grass pollen/m³ air per 90-minute observation period. The grass pollen were released through the air purifier device with the filter cartridge in place.

Test parameter and symptom severity

The following parameters were recorded before, during, and after the exposure:

- Symptoms of the eyes, nose, and bronchia every 10 min.
- Peak nasal inspiratory flow (PNIF) every 30 min.
- Spirometry (FEV₁, forced expiratory volume in 1 s) and peak expiratory flow (PEF) before and after exposure.

The total symptom score (TSS) was compiled by evaluating the following symptoms:

- Eyes: itching, irritation, redness, tearing.
- Nose: itching, sneezing, runny nose, congestion.
- Bronchial: wheezing, coughing, shortness of breath, asthma.

All symptoms were scored as: no symptoms = 0, mild = 1, moderate = 2, severe = 3. The TSS scale allows a maximal symptom score of 12 points per organ. Since nasal symptoms account for over 80% of total symptoms, the total nasal symptom score (TNSS) is

a critical parameter for determining the results of intervention in allergic rhinitis.

Participants

Four non-smoking participants (male = 3, female = 1; age = 25–29 years) were asked for their written and oral consent in an in-depth discussion with the study doctor who provided information on study participation and data storage. The inclusion criteria were age >18 years with a diagnosis of allergic rhinitis and/or conjunctivitis for at least two years during the months of the respective pollen season and a positive skin prick test with grass pollen allergen (>3 mm). They had no completed or currently immunotherapy within the last five years and no treatment with an antihistamine during the last week before challenge. The study based on a positive vote from the ethics commission of Charité, Universitätsmedizin Berlin, Germany.

Results

Preliminary tests During the 30-minute exposure period with the active air purifier but without pollen in the chamber, practically no symptoms occurred (Fig. 2). There was a very mild bronchial irritation less than 1 point (0.75 points) at the baseline value, which lessened after 10 to 30 min. Only minimal symptoms were documented after 30 min in the eyes and after 10 and 30 min in the nose.

Exposure tests with grass pollen with air purifier in sham mode During the 90-minute exposure with a concentration of 4000 grass pollen/m³, allergic symptoms occurred on the nose, and to a lesser degree on eyes and bronchi. In the first run the probands reached a plateau in the TSS after 60 min above 6 points. In the second run they reached 4 points after 60 min and had no further increase

Fig. 3 Progression of the total symptom score (TSS) in four participants during exposure to 4000 grass pollen over a 90-minute period with and without the effect of the filter of an air purifier

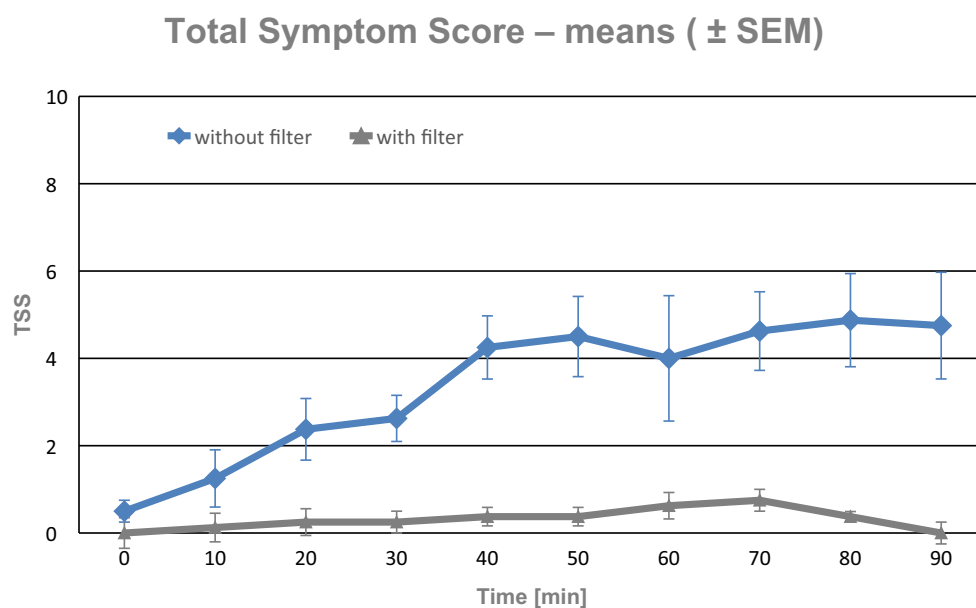
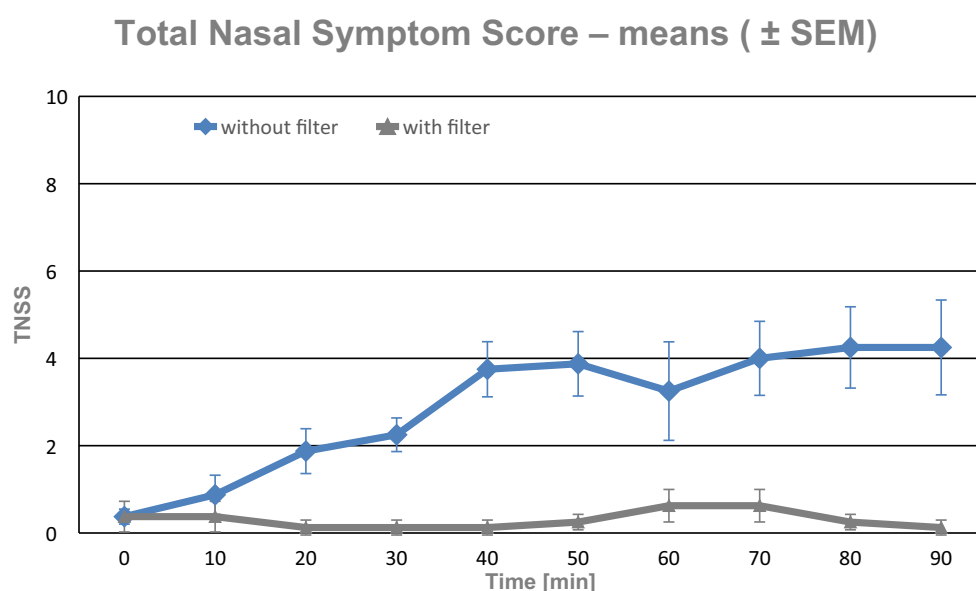


Fig. 4 Progression of the total nasal symptom score (TNSS) in four participants during exposure to 4000 grass pollen over a 90-minute period with and without the effect of the filter of an air purifier



(Fig. 3). The TNSS showed a similar development (Fig. 4).

Exposure tests with grass pollen with active air purifier During the 90-minute exposure with identical pollen concentration and test conditions the probands developed nearly no symptoms on nose, eye, and bronchi. Both, TSS and TNSS remained under 1 point – similar as during the exposure of the pollen-free air outlet from the air purifier (Figs. 3 and 4).

Discussion

Pollen allergy is the most frequent allergic disease in the world. In Germany, at least 14.8% of adults [2] and

10.7% of children and adolescents [12] are suffering from allergic rhinoconjunctivitis due to pollen.

The natural exposure to pollen is typically an outdoor exposure. The rationale of our study on the efficacy of an air cleaner are reports on pollen in homes, too. Yli-Panula & Rantio-Lehtimäki reported on birch pollen allergens in indoor settled dust which was lower than outdoors dust [5]. The mean concentration of allergenic activity indoors peaked three weeks later than outdoors and the birch allergenic activity was still detected two months after the birch peak pollen period. Also, cedar pollen allergen (Cry j I) was still found in house dust collected two weeks after airborne *C. japonica* pollen had disappeared outside [13]. Therefore, indoor dust may be an important cause of birch pollen-induced symptoms after the season.

Fahlbusch and colleagues reported on considerable high level of grass pollen allergens in indoor dust even during periods when no grass pollen was present in the atmosphere suggesting that indoor pollen may be an important cause of pollen-allergy symptoms outside of season [6]. They measured the major grass pollen allergen in samples from five randomly selected homes in Germany. Dust samples were collected from floor of living rooms, bedrooms, children's rooms, and mattresses during the period of June 1995 to August 1998. Phl p 5 was detected in 67% of the samples analyzed ($n = 4760$) with a range between undetectable ($<0.03 \mu\text{g/g}$ dust and $81 \mu\text{g/g}$ dust). The levels were significantly higher in the dust from living rooms (geometric mean $0.117 \mu\text{g/g}$ dust) or bed room floors (geometric mean $0.098 \mu\text{g/g}$ dust) than in mattresses (geometric mean $0.043 \mu\text{g/g}$ dust).

Phl p 5 content indoors also reflected the different quantities of pollen counts of annual courses. During pollination period, the concentrations were two times higher than out of grass pollination season [8]. Quantification of birch and grass pollens and their allergens in indoor air of two school and two office rooms showed that the indoor air carried substantial amounts of pollen allergens [7]. *Parietaria judaica* allergenic activity was measured in Italy in the dust of rooms with the balcony open on some days and closed on others [14]. Statistical analysis indicated a significant correlation between outdoor allergen levels and indoor allergen levels with balcony open but not with balcony closed.

It was shown that frequent cleaning (vacuuming of carpets) reduces the indoor exposure to grass pollen allergens [8] but modern technology of air cleaners may offer an easier way of avoiding exposure to pollen for hay-fever sufferers in their homes.

There are few published data on the efficacy of air cleaners in reducing pollen counts or pollen allergen concentrations in indoor air or indoor dusts. In one study, the effect of electrostatic air cleaning (indoor air samples) on birch and grass pollen was studied under authentic working conditions in May and July 1999 in two street-level shops [15]. The average concentration of airborne indoor birch pollen allergen in the shop with air cleaning was estimated to be $20 \pm 9 \text{ SQ/m}^3$ (mean \pm SD) compared to $31 \pm 17 \text{ SQ/m}^3$ (mean \pm SD) of that without. The air cleaner reduced the indoor air birch pollen allergen concentration by on average 26 to 48% ($p < 0.05$). Corresponding figures for airborne indoor grass pollen allergen concentrations were $14 \pm 7 \text{ SQ/m}^3$ and $17 \pm 8 \text{ SQ/m}^3$, indicating a statistically non-significant (t-test) average 18% reduction of allergens by air cleaning. In another study, electrostatic air cleaning in an office room reduced its grass pollen allergen concentrations by more than 95% as compared to the control room [7].

In our study, we first documented that the airflow from the air cleaner itself is not irritating the nose or eye of the users; there were no clinically relevant

symptoms on both organs. This result may have clinical importance – the air cleaner can stay near to a bed or chair and is not inducing any harm itself because of his air flow.

The new developed technology of very standardized pollen exposures in specifically designed chambers allows measuring the efficacy of an air cleaner in detail, comparing the same concentration of pollen in the ambient air with and without the cleaner. Using a validated concentration of $4000 \text{ grass pollen/m}^3$ air, four patients with allergic rhinitis due to grass pollen developed a total symptom score of about 6 points. This severity of nasal symptoms is similar to nasal symptom severity reported in Germany by the users of an electronic patient diary on allergy symptoms in a pollen App [16] during grass pollen season.

In the study, the pollen influx was directed to the air purifier, in real life condition the device would take the airborne pollen from the room but the efficacy should be in the same range. The number of probands is small because of limits in financial resources.

Grass pollen were chosen for provocation due to the fact that they have a globally broad geographical extension and a very high prevalence of sensitization [9]. Pollen concentrations are lower outside than we used in the chamber but urban air pollution may affect airborne allergenic pollen [17] and therefore induces more severe allergic reactions even with a much lower amount of pollen in the air as is it was used in chamber studies. Also, the influence of a smaller micronic atmospheric aerosol fraction outside the chamber [18] may influence the relation between pollen counts and symptoms.

Under identical and repeated exposure conditions over 90 min, the air cleaner significantly inhibited the symptoms of the probands under a severity level of 1; that means that they had no more allergic symptoms on eyes, nose, or bronchi. The results show that the pollen concentration was effectively influenced by the air cleaner.

Conclusions

The presence of the tested air purifier in active use (i. e., used as intended) did not result in any irritations of nose, eyes, or bronchia in unmedicated persons with allergic rhinitis due to grass pollen.

The exposure in an exposure chamber to $4000 \text{ grass pollen/m}^3$ over a 90-minute period under standardized conditions led to the development of nasal symptoms on a scale of up to 6 points as in real life conditions.

The presence of the tested air purifier, used as intended, resulted in the complete prevention of symptoms in the nose, eyes, and bronchia in the tested pollen allergy sufferers. The level of symptom severity was less than 1 point in both the total symptom score and the total nasal symptom score.

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Conflict of interest K.-C. Bergmann, T. Sehlinger, J. Gilde-meister and T. Zuberbier declare that they have no competing interests.

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