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Effects of Mechanical Drying on the Removal of Pollen Allergens

Young-Jin Choi[a] Jungha Park[b] Sujin Seong[c] Jae-Won Oh[a]

[a]Department of Pediatrics, Hanyang University Guri Hospital, Guri, Republic of Korea; [b]Digital Appliances R&D Center, Samsung Electronics Co, Suwon, Republic of Korea; [c]Advanced R&D Team, Digital Appliances, Samsung Electronics Co, Suwon, Republic of Korea

Keywords
Mechanical dryer · Pollen · Pollen allergen · Fabric contamination · Removal ratio

Abstract
Purpose: Pollen may spread indoors through clothes contaminated during outdoor activities. This study aimed to evaluate the pollen removal efficacy of a mechanical dryer. ***Methods:*** Cotton clothes served as laundry, and fabrics measuring 2 × 5 cm served as test samples. Pollen was spread evenly on the test fabrics. The fabrics were then fixed on the cloth and left for 8 h to imitate real-life conditions. This experiment was conducted under 2 conditions, wet (after washing clothes) and dry (without washing). After drying, we counted pollen on the test fabrics to evaluate the pollen removal rate. We measured the remaining allergens in extracts from the contaminated fabrics after mechanical drying. The concentrations of allergens (Amb a 1, Bet v 1, Crp j 1, and Phl p 1) in each extracted solution were measured using 2-site ELISA. ***Results:*** For ragweed, Japanese cedar, birch, and timothy grass, the mean pollen removal ratios for the dry samples were 99.88 ± 0.09%, 99.96 ± 0.03%, 99.89 ± 0.02%, and 99.82 ± 0.11%, respectively, and those for the wet samples were 98.83 ± 0.87%, 97.91 ± 1.81%, 97.29 ± 1.19%, and 96.3 ± 0.92%, respectively. Further, for the pollen allergens Amb a 1 [ragweed], Crp j 1 [Japanese cedar], Bet v 1 [birch], and Phl p 1 [timothy grass], the mean pollen allergen removal ratios for the dry samples were 99.81 ± 0.06%, 99.94 ± 0.23%, 99.90 ± 0.11%, and 99.84 ± 0.17%, respectively, and those for the wet samples were 98.11 ± 0.14%, 96.04 ± 1.52%, 97.21 ± 0.83%, and 95.23 ± 0.92%, respectively. There was no statistically significant difference for each species. ***Conclusions:*** Mechanical drying effectively removed pollen and allergens from dry and wet fabrics. We expect that further studies on the removal of other indoor allergens would contribute to improved environmental control for allergy patients.

Introduction

Pollen is the second-most common cause of allergy after house dust mites. Allergenic plants are mainly distributed in well-populated residential areas near cities [1]. Pollen is recognized as an inhaled allergen that aggravates respiratory allergies. However, direct contact of the skin

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karger@karger.com
www.karger.com/iaa

Jae-Won Oh
Department of Pediatrics
Hanyang University Guri Hospital
249-1 Gyomun-dong, Guri-si, Guri, Gyunggi-do 11923 (Republic of Korea)
jaewonoh@hanyang.ac.kr

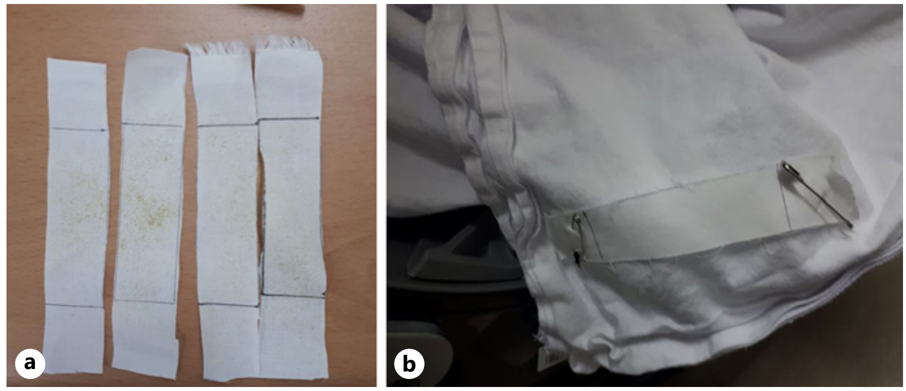

Fig. 1. a Pollen-sprayed test fabric. **b** Test sample fabric attached to clothes.

Color version available online

Fig. 2. a Fabric was stained using Calberla's fuchsin solution. **b** Counting number of pollen using a microscope.

Color version available online

with pollen-contaminated clothes or bedding can also aggravate atopic dermatitis. Consequently, the thorough environmental control of pollen could help prevent an exacerbation of asthma and rhinitis symptoms as well as atopic dermatitis [2–5]. Circulating air is a major means of transportation of pollen into homes, and large amounts of pollen are blown as dust through windows and ventilator fans. Pollen adheres very strongly to fabric materials [6–9]. A previous study reported that more than half of all pollen distributed on the surfaces of futons or laundry was retained even after hand-brushing or shaking [5, 6]. Recent studies have investigated the role of clothing as a vector for the transportation of airborne particles into houses, thereby contributing to inhalation exposure [5–7]. Thereafter, these particles are released to the agitation of contaminated fabrics, indicating that clothing could facilitate the transfer of airborne particles [8, 9]. Therefore, efficient strategies must be employed for removing pollen from clothes contaminated in outdoor environments and fabrics contaminated by the movement of air through windows or fans. In this study, we aimed to investigate whether a mechanical dryer alone could be used for environmental allergen control rather than for simply drying laundry. We investigated the ability of a mechanical dryer to eliminate birch, Japanese cedar, ragweed, and timothy grass pollen, which are major allergenic pollens in Korea. The pollen removal function of a mechanical dryer was evaluated in terms of the decrease in the numbers of pollen particles and allergens on fabrics.

Materials and Methods

Testing was conducted using a commercial mechanical dryer (Samsung Electronics, Suwon, Korea) and standard pollen of ragweed, Japanese cedar, birch, and timothy grass (Thermo Fisher Scientific Allergon, Phardia, Uppsala, Sweden). Cotton cloth was used as the laundry, and fabrics with a dimension of 2 × 5 cm^2 were used as the test samples. Pollen was spread evenly on these test samples, and the fabric was fixed to the cloth using a clothespin. The experiment was conducted under 2 conditions – wet and dry – because mechanical clothes dryers are traditionally used to dry laundry after washing. We prepared a wet cloth and wet test fabrics to mimic the state of a fabric that had been washed. The wet load comprised 6 kg of cloth with a moisture content exceeding 65%; the wet test fabrics were fixed with pollen sprayed on the wet clothes. The dry load comprised 4 kg of dry cotton cloth; the dry test fabrics were fixed with pollen sprayed on the dry clothes. We prepared 5 contaminated fabrics for each type of pollen. One fabric was designated as the control fabric, and the others were designated as the test fabrics. The latter were fixed to the cloth and dried using a mechanical clothes dryer, as shown in Figure 1. For the experiment, we assumed that the same amount of pollen had been sprayed on each piece of fabric in the control and

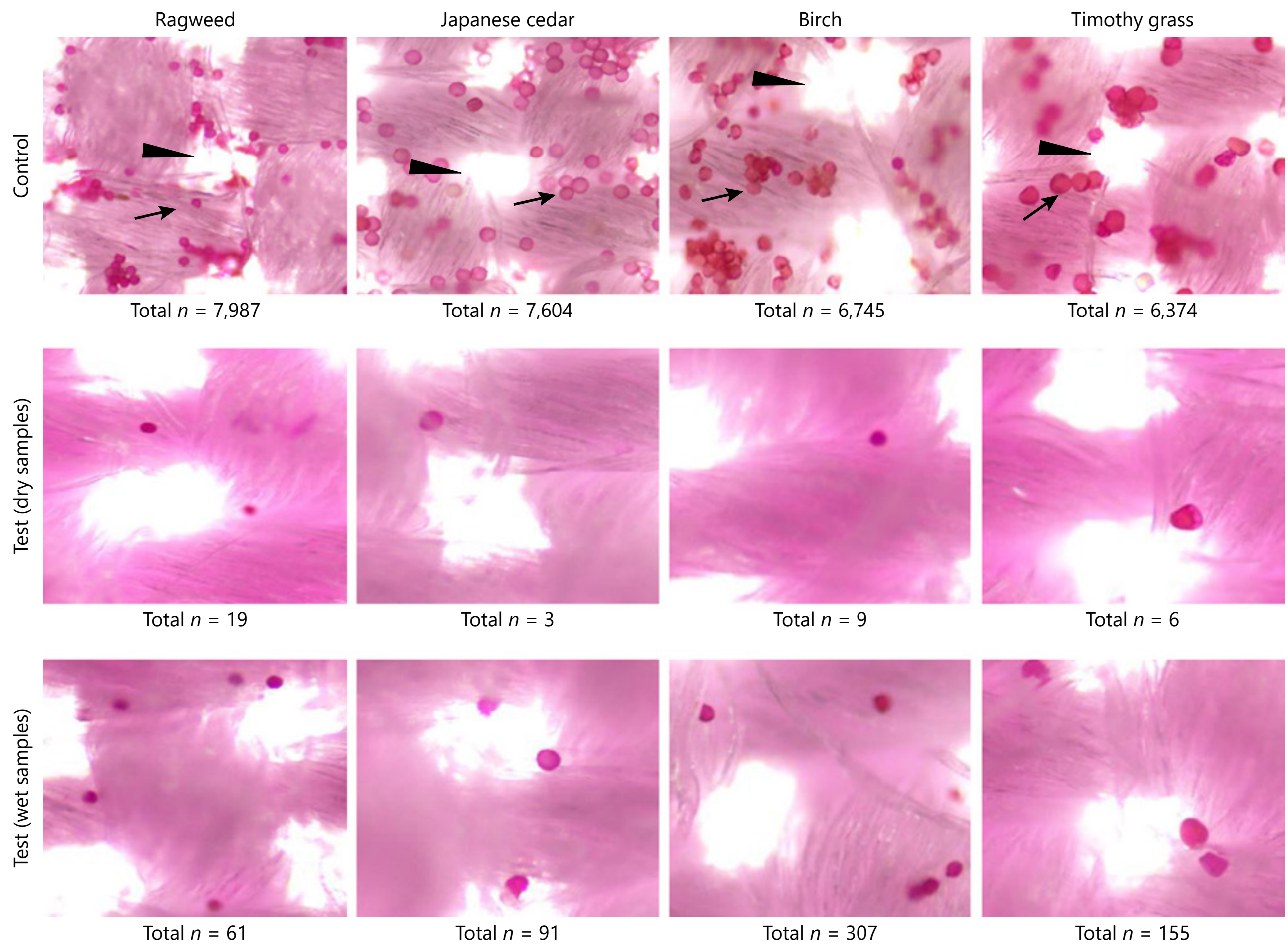

Fig. 3. Representative images of 24-point microscope imaging used to analyze pollen removal from dry and wet samples. Part of each fabric was stained, covered with a cover glass, divided into 24 points, and imaged. Pollen removal ratios for dry samples: ragweed: 99.88%, Japanese cedar: 99.96%, birch: 99.89%, and timothy grass: 99.82%. Pollen removal ratios for wet samples: ragweed: 98.83%, Japanese cedar: 97.91%, birch: 97.29%, and timothy grass: 96.30%. Arrow: pollen. Triangle arrow: fabric holes.

test samples. After the completion of drying using the mechanical clothes dryer, we detached the test fabrics. Part of each fabric was stained using Calberla's fuchsin solution, covered with a cover glass, divided into 24 points, and imaged using a microscope at ×200 magnification, as shown in Figure 2. The pollen particles were counted, and the numbers of pollen particles at each point were summed. We also counted pollen particles on the control fabric for comparison, as shown in Figure 3. Subsequently, the pollen removal ratio was calculated as the ratio of the pollen count on the test samples (*A*) to the pollen count on the control samples (*B*) (%): $(B - A)/B \times 100$. For pollen of ragweed, Japanese cedar, birch, and timothy grass, the mean pollen removal ratios for the dry samples were 99.85, 99.98, 99.88, and 99.81%, respectively, and those for the wet samples were 98.63, 95.23, 96.04, and 97.54%, respectively. To evaluate the pollen allergen removal ratios, pollen-contaminated control and test fabric samples were each placed in a test tube containing 10 mL of borate-buffered saline (170 mmol/L boric acid and 125 mmol/L sodium chloride, pH 7.4) and agitated in an orbital shaker at 23–25°C for 18 h. Subsequently, 4 types of 2-site ELISAs (Indoor Biotechnologies, Ltd., Cardiff, UK) corresponding to the 4 types of pollen allergens (Amb a 1 [ragweed], Crp j 1 [Japanese cedar], Bet v 1 [birch], and Phl p 1 [timothy grass]) were used to measure the concentrations of allergens on the fabrics. Thereafter, the pollen allergen removal ratios were calculated as the ratio of the amount of pollen allergen remaining on the test fabrics (*A*) to the amount of pollen allergen remaining on the control fabrics (*B*) (%): $(B - A)/B \times 100$. Statistical analyses were performed using SPSS (version 19.0, IBM, Chicago, IL, USA). We used a one-way ANOVA to evaluate the changes in the concentrations of allergens after mechanical drying. *p* values <0.05 were considered to indicate statistical significance.

Table 1. Pollen removal ratios for dry and wet samples

Pollen	Average pollen removal ratios, %	
	dry samples	wet samples
Ragweed	99.88±0.09	98.83±0.87
Japanese cedar	99.96±0.03	97.91±1.81
Birch	99.89±0.02	97.29±1.19
Timothy grass	99.82±0.11	96.30±0.92

Table 2. Pollen allergen removal ratios for dry and wet samples

Allergen	Average pollen allergen removal ratios, %	
	dry samples	wet samples
Amb a 1 (ragweed)	99.81±0.06	98.11±0.14
Crp j 1 (Japanese cedar)	99.94±0.23	96.04±1.52
Bet v 1 (birch)	99.90±0.11	97.21±0.83
Phl p 1 (timothy grass)	99.84±0.17	95.23±0.92

Results

Pollen Removal Ratios after Running Mechanical Drying

The average number of pollens distributed on each fabric was 7,177.5 ± 746.07 grains (minimum of 6,374 grains and maximum of 7,987 grains). For the pollen of ragweed, Japanese cedar, birch, and timothy grass, the mean pollen removal ratios (mean ± SD) for the dry samples were 99.88 ± 0.09%, 99.96 ± 0.03%, 99.89 ± 0.02%, and 99.82 ± 0.11%, respectively, and those for the wet samples were 98.83 ± 0.87%, 97.91 ± 1.81%, 97.29 ± 1.19%, and 96.3 ± 0.92%, respectively (Table 1; Fig. 1). There was no statistically significant difference for each species.

Pollen Allergen Removal Ratios after Mechanical Drying

For the pollen allergens Amb a 1 [ragweed], Crp j 1 [Japanese cedar], Bet v 1 [birch], and Phl p 1 [timothy grass], the mean pollen allergen removal ratios for the dry samples were 99.81 ± 0.06%, 99.94 ± 0.23%, 99.90 ± 0.11%, and 99.84 ± 0.17%, respectively, with all values exceeding 99% despite the differences between species, and those for the wet samples were 98.11 ± 0.14%, 96.04 ± 1.52%, 97.21 ± 0.83%, and 95.23 ± 0.92%, respectively, with all values exceeding 95% (Table 2). There was no statistically significant difference for each species.

Discussion

Although mechanical washing is a highly efficient method for environmental control, it is significantly inconvenient to wash clothes every day considering the amount of time required. Mechanical dryers were developed to dry laundry after washing. In our study, we evaluated whether these mechanical dryers alone could be used to remove pollen and its allergens. To the best of our knowledge, no previous study has investigated whether the use of these dryers could eliminate indoor allergens. We found that mechanical drying effectively reduced the number of pollen particles and also eliminated allergens from dry and wet fabrics. However, this study has some limitations. We did not evaluate the effects of the use of mechanical dryers on the clothes of allergy patients. Therefore, we can only assume that the reductions in pollen and allergen counts would effectively reduce patient symptoms. In conclusion, our study demonstrated that a mechanical clothes dryer could be used to remove more than 95% of pollen particles and related allergens from dry or wet fabrics. The mechanical clothes dryer was more effective in removing particles from dry fabrics than from wet fabrics; it achieved removal rates of nearly 99.9% for all pollen counts and allergens in the case of dry fabrics. We believe that such decreases in pollen and allergen counts would help reduce the symptoms experienced by allergy patients. Moreover, we expect that further studies on the removal of other indoor allergens would likely contribute to greater environmental control for allergy patients.

Statement of Ethics

This study was approved by the Hanyang University Guri Hospital IRB committee (GURI 2018-07-029-001).

Conflict of Interest Statement

Young-Jin Choi and Jae-Won Oh have no conflicts of interest to declare pertaining to this article. Jungha Park and Sujin Seong are employees of Samsung Electronics.

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Author Contributions

Y.-J. Choi, J. Park, and S. Seong conducted the experiments and collected and analyzed the data. J.-W. Oh was a major contributor in writing the manuscript. All authors have read and approved the final manuscript.

References

1 Oh JW, Kang IJ, Kim SW, Kook MH, Kim BS, Cheong JT, et al. The association between the concentration of pollen and outbreak of pollinosis in childhood. Pediatr Allergy Respir Dis. 2009;19:4–11.

2 Licina D, Nazaroff WW. Clothing as a transport vector for airborne particles: camber study. Indoor Air. 2018;28(3):404–14.

3 Marzia B. Pollen attachment in common materials. Aerobiologia. 2015;31:261–70.

4 Takahashi Y, Takano K, Suzuki M, Nagai S, Yokosuka M, Takeshita T, et al. Two routes for pollen entering indoors: ventilation and clothes. J Investig Allergol Clin Immunol. 2008;18(5):382–8.

5 Choi SY, Lee IY, Sohn JH, Lee YW, Shin YS, Yong TS, et al. Optimal conditions for the removal of house dust mite, dog dander, and pollen allergens using mechanical laundry. Ann Allergy Asthma Immunol. 2008;100(6):583–8.

6 Okuda M, Ohkubo K, Gotoh M, Ishida Y. [Natural airborne pollen contamination of clothes and facial skin]. Arerugi. 2005;54(6):555–8.

7 Jantunen J, Saarinen K. Intrusion of airborne pollen through open windows and doors. Aerobiologia. 2009;25(3):193–201.

8 Morgan WJ, Crain EF, Gruchalla RS, O'Connor GT, Kattan M, Evans R III, et al. Results of a home-based environmental intervention among urban children with asthma. N Engl J Med. 2004;351(11):1068–80.

9 Eggleston P. Improving indoor environments: reducing allergen exposures. J Allergy Clin Immunol. 2005;116(1):122–6.