## ORIGINAL ARTICLE

# Improvement of Atopic Dermatitis Severity after Reducing Indoor Air Pollutants

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**Background:** Recent epidemiologic studies have shown that environmental contaminants such as air pollution and tobacco smoke play an important role in the pathophysiology of atopic dermatitis (AD). **Objective:** The aim of this study was to evaluate the relationship between the severity of AD and indoor air pollution. **Methods:** The study population consisted of 425 children from 9 kindergartens, Korea. The authors surveyed the prevalence of AD and evaluated disease severity by the eczema area and severity index (EASI) score and investigator's global assessment (IGA). After measuring indoor air pollution, a program to improve indoor air quality was conducted in 9 kindergartens. Seven months later, the prevalence and disease severity were evaluated. **Results:** The initial prevalence of AD was 8% and the mean EASI score was 2.37. The levels of particulate material 10 ($PM_{10}$) and carbon dioxide ($CO_2$) were higher in some kindergartens compared to the normal values. Subsequent to the completion of the indoor air quality improvement program, the mean $PM_{10}$ level was significantly decreased from 182.7 to 73.4 $\mu g/m^3$. After the completion of the program, the prevalence of AD and the mean EASI were decreased, and the changes were both statistically significant. The mean number of hospital visits decreased from 1.3 per month during the first survey to 0.7 per month during the second survey, which was statistically significant.

**Conclusion:** Indoor air pollution could be related to AD. The reduction of $PM_{10}$ through improving indoor air quality should be considered in kindergartens and schools in order to prevent and relieve AD in children. **(Ann Dermatol 25(3) 292~297, 2013)**

-Keywords-
Atopic dermatitis, Improvement, Indoor air pollutants, Severity

## INTRODUCTION

Atopic dermatitis (AD) is a chronic, itching and eczematous skin disease, which particularly affects subjects in early or late childhood. The prevalence of AD has been reported to be between 5% and 10% in the general population, and it has been increasing continuously worldwide in the recent decades[1]. This increase suggests that the pathogenesis of AD may be attributed to both genetic predisposition and environmental factors. There is much disagreement between the results of several epidemiological surveys, which studied the relationships between AD and environmental factors. Some studies portrayed that more industrialization and urbanization augments the prevalence of AD, whereas others presented no such relationship[2-5].

There have been several epidemiological studies on the relationship between AD and air pollution. However, there is little clinical evidence in the literature. A few studies reported the relationship between AD and the environment. Wen et al.[6] showed that fungus on walls, house renovation and house painting are significantly associated with AD. Arnedo-Pena et al.[7] reported that the annual average concentration of carbon monoxide (CO) is also associated with the prevalence of AD.

This study is designed to evaluate the effect of indoor air quality on the severity of AD. We surveyed the prevalence and severity of AD in 9 kindergartens in Guro-gu, Seoul in collaboration with the Guro-gu public health center. After improving the indoor air quality through frequent cleaning and vacuuming, we evaluated the changes in clinical signs and symptoms among children with AD.

## MATERIALS AND METHODS

### Subjects

Of the 301 kindergartens in Guro-gu, Seoul, 9 were randomly selected for on-site surveys, which included physical examinations by a dermatologist. A total of 425 children (males, 210; females, 215) aged from 1 to 5 years were enrolled in the study. AD patients were diagnosed by a single dermatologist during the study. Exclusion criteria included any skin disorders other than AD in the area to be treated as well as children with any other systemic diseases. We received voluntary informed consent form the patients' parents.

### Methods

#### 1) Program for improving indoor air quality

Indoor air quality measurements included indoor temperature, humidity, particulate materials ($PM_{10}$), CO, carbon dioxide ($CO_2$) and formaldehyde (HCHO) in accordance with the official test standard of indoor air quality (Notification no. 2008-73 of the Ministry of Environment), gauged by a simplified measuring instrument (Model: LD-3B; Sibata Scientific Technology Ltd., Tokyo, Japan). Each kindergarten conducted general cleaning every week during the first survey and changed the frequency of general cleaning to every 2 or 3 days during the second survey. To improve indoor air quality, several daily practices were instituted: (1) elimination of fine dust, cobweb and mold spores on the walls, ceilings, bookshelves, floors and bedding; (2) steam sterilization of chairs, desks and other furniture in the hall and the gymnasium; and (3) removal of floating matters and mites in the bedding by steam cleaning.

#### 2) Evaluation of atopic dermatitis

AD was diagnosed based on the Korean diagnostic guideline for AD[8] and the patients were evaluated by a single dermatologist during the study. The objective skin manifestations of AD patients were checked for the point prevalence at the time of examination. The extent of skin lesions was estimated based on the Nine's rule and the severity of AD was evaluated by the eczema area and severity index (EASI) score and investigator's global assessment (IGA) measurement (a static 6-point measure of disease severity based on an overall assessment of skin lesions: 0 = clear, no inflammatory signs of AD; 1 = almost clear, just perceptible erythema and just perceptible population/infiltration; 2 = mild disease, mild erythema and population/infiltration; 3 = moderate disease, moderate erythema and moderate population/infiltration; 4 = severe disease, severe erythema and severe population/infiltration; and 5 = very severe disease, severe erythema and severe population/infiltration with oozing/crusting)[9]. Their parents were asked on the phone as to whether they regarded their children as AD patients or not. The evaluation and improvement of indoor air quality in kindergartens were attempted in collaboration with the Guro-gu public health center.

The first survey was conducted in order to collect data on the prevalence, severity and hospital visits of AD among children in kindergartens of Guro-gu, Seoul, between March and April of 2009. The second survey was conducted between November and December of 2009 in order to assess changes after the completion of the program for improving indoor air quality. The mean number of hospital visits per month in AD patients was calculated for each survey.

### Statistical analysis

The paired $t$ test was applied in order to compare the EASI score, decrease in the number of hospital visits and $PM_{10}$/$CO_2$ level between the first and second surveys. A $p$-value of $< 0.05$ was considered as being statistically significant.

Table 1. Baseline values of indoor air in nine kindergartens

| | Temperature ($^{\circ}$C) | Moisture (%) | $PM_{10}$ ($\mu g/m^3$) | CO (ppm) | $CO_2$ (ppm) | HCHO ($\mu g/m^3$) |
|---|---|---|---|---|---|---|
| Standard criteria | 18~28 | 30~60 | 100 | 25 | 1,000 | 120 |

HCHO: formaldehyde.

## RESULTS

### Program for improving indoor air quality

Table 1 presents the baseline value of indoor air quality. The baseline value of $PM_{10}$ is usually under 150 $\mu g/m^3$, particularly under 100 $\mu g/m^3$ in medical institutes and child, elderly and postpartum care centers; hence, the authors considered that an optimal value of $PM_{10}$ in kindergartens should be under 100 $\mu g/m^3$.

Table 2 conveys the changes in $PM_{10}$ and $CO_2$ levels during the first and second surveys. CO and HCHO were not detected in any kindergarten. In the first survey, all of the 9 kindergartens showed a higher $PM_{10}$ level than the baseline value, and 3 kindergartens showed a higher $CO_2$ level than the baseline value. In the second survey after the program, the $PM_{10}$ level dropped under the baseline value in 7 of the 9 kindergartens. Three kindergartens still showed a higher $CO_2$ level. Five kindergartens satisfied the environmental standards for both $PM_{10}$ and $CO_2$ levels. The mean $PM_{10}$ level decreased from $182.7 \pm 23.68$ to $73.4 \pm 22.05$ $\mu g/m^3$ with statistical significance, while the mean $CO_2$ level did not change significantly (from $934 \pm 384.4$ to $1,040 \pm 540.4$ ppm). The detection sites included 2 classrooms, 4 study rooms and 3 corridors. All sites showed improvement in the $PM_{10}$ level after the program; yet, in 3 study rooms, the $CO_2$ level increased.

### Prevalence of AD

During the first survey, 123 children (28.9%, 63 boys and 60 girls) were reported as AD patients by their parents via telephone interviews. However, 34 (8%, 20 boys and 14 girls) of the 425 children were diagnosed with AD by

medical examination. The parents of 8 children (23.5%; 5 boys and 3 girls) of the 34 AD patients reported that their children had no AD. The prevalence of AD in each kindergarten varied from 3% to 15% (Table 3); however, there were no statistically significant differences between the 9 kindergartens ($p > 0.05$). However, between the first and second surveys, 15 children moved to other kindergartens or dropped out before the second survey, leaving the study with 410 children. During the second survey, 3 children were newly diagnosed with AD, and 6 of 34 AD patients in the first survey moved to other kindergartens; thus, 31 (7.6%, 19 boys and 12 girls) of the total 410 children were classified as having AD.

The mean EASI score decreased from $2.37 \pm 1.08$ in the first survey to $1.19 \pm 1.25$ in the second survey (Fig. 1),

**Table 3.** Prevalence of atopic dermatitis in 9 kindergartens during first survey

| Kindergarten | Subjects | AD patients | Prevalence (%) |
|---|---|---|---|
| A | 67 | 5 | 7.5 |
| B | 92 | 3 | 3.3 |
| C | 66 | 7 | 10.6 |
| D | 27 | 4 | 14.8 |
| E | 36 | 4 | 11.1 |
| F | 13 | 1 | 7.7 |
| G | 40 | 4 | 10.0 |
| H | 66 | 4 | 6.1 |
| I | 18 | 2 | 11.1 |
| Total | 425 | 34 | 8.0 |

34 of the 425 patients were diagnosed with atopic dermatitis (AD). The average prevalence was 8% and varied from 3% to 15% in each kindergarten.

**Table 2.** Measurement results of indoor air in nine kindergartens

| Kindergarten | Spot | First | | Second | |
|---|---|---|---|---|---|
| | | $PM_{10}$ (100 $\mu g/m^3$) | $CO_2$ (1,000 ppm) | $PM_{10}$ (100 $\mu g/m^3$) | $CO_2$ (1,000 ppm) |
| A | Classroom | 180 | 868 | 82.4 | 622 |
| B | Study room | 210 | 1,800 | 70.0 | 980 |
| C | Corridor | 188 | 513 | 51.2 | 540 |
| D | Study room | 147 | 1,061 | 50.7 | 1,311 |
| E | Classroom | 174 | 955 | 57.9 | 844 |
| F | Corridor | 208 | 678 | 55.6 | 818 |
| G | Study room | 180 | 1,132 | 101.4 | 1,946 |
| H | Study room | 208 | 800 | 81.1 | 1,821 |
| I | Corridor | 150 | 600 | 110.7 | 478 |
| Mean ± standard deviation | | $182.7 \pm 23.68$ | $934.0 \pm 384.40$ | $73.4 \pm 22.05$ | $1,040.0 \pm 540.40$ |

During the first survey, excessive particulate material 10 ($PM_{10}$) level and $CO_2$ were detected in 9 and 3 of the 9 kindergartens, respectively. During the second survey, the $PM_{10}$ level was significantly decreased in all kindergartens, and 7 of the 9 kindergartens was decreased below the baseline value. The average changes in $CO_2$ levels were variable slightly increased. The $CO_2$ level increased in the study room with poor ventilation.
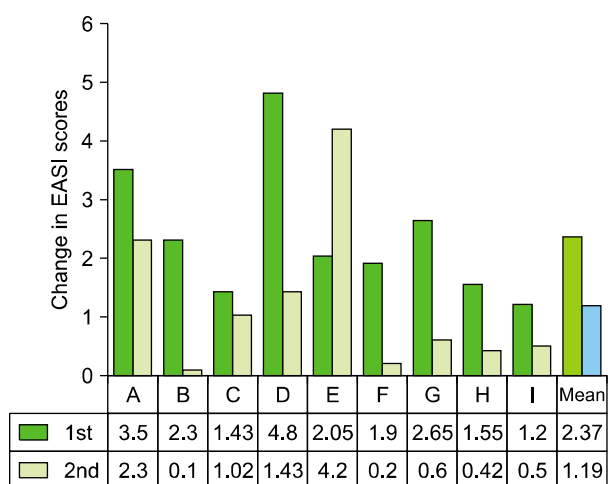
**Fig. 1.** The comparison of atopic dermatitis improvement and the EASI score between the first and second surveys at 9 different kindergartens (A to I). The mean EASI score decreased from 2.37 in the first survey to 1.19 in the second survey ($p < 0.05$). All kindergartens except 1 showed a decrease in the EASI score during the second survey. EASI: eczema area and severity index.



**Fig. 2.** Atopic dermatitis patients were evaluated and grouped according to the IGA score as follows: 20 patients in IGA 1 (almost clear), 8 patients in IGA 2 (mild) and 6 patients in IGA 3 (moderate). After performance of the program, 9 patients were in IGA 0 (clear), 15 patients in IGA 1, 5 patients in IGA 2 and 5 patients in IGA3. IGA: investigator's global assessment.



**Fig. 3.** The mean extent of the skin lesion decreased from 7.06% in the first survey to 4.22% in the second survey ($p < 0.05$).

and the difference was statistically significant ($p < 0.05$).

The IGA score showed much improvement after the completion of the program. The IGA scores in the first survey were as follows: IGA 1 (almost clear) in 20 children, IGA 2 (mild) in 8 children and IGA 3 (moderate) in 6 children. In the second survey, the score was changed as follows: IGA 0 (clear) in 9 children, IGA 1 (almost clear) in 15 children, IGA 2 (mild) in 5 children and IGA 3 (moderate) in 2 children (Fig. 2).
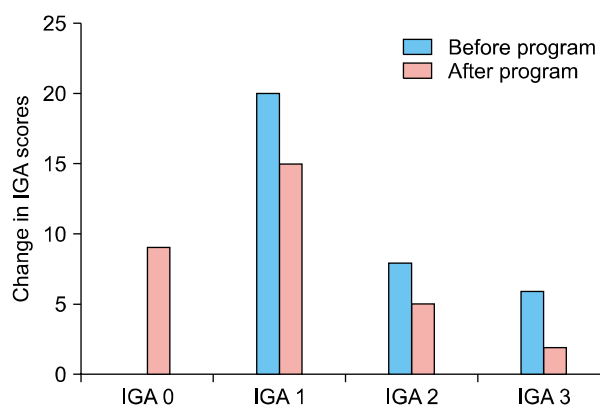
The mean extent of the skin lesion decreased from 7.06% in the first survey to 4.22% in the second survey with statistical significance ($p < 0.05$) (Fig. 3).

The mean number of hospital visits of 15 AD patients decreased from 1.3 per month in the first survey to 0.7 per month in the second survey, and the difference was statistically significant ($p < 0.05$). During this period, none of the patients required additional hospital visits.
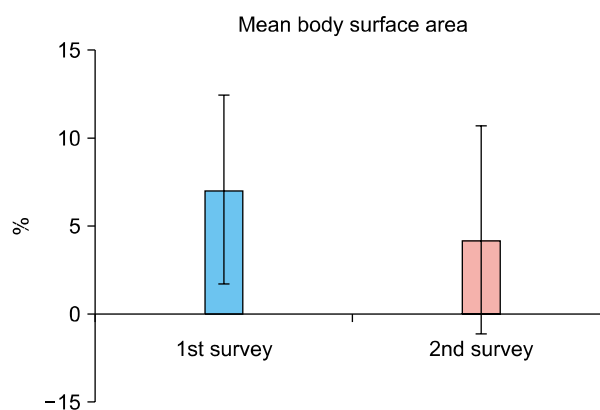
## DISCUSSION

The prevalence of allergic diseases including AD, asthma and allergic rhinitis has increased, keeping pace with industrial development due to multifactorial causes. Environmental pollution has been considered as an exacerbating factor of AD; however, only a few studies have supported this assumption.

Interior decoration materials and building materials used in Western-style buildings for durability and insulation are known to cause indoor air pollution. As most buildings in Korea are Western-style, the detection of these materials is

essential. In Korea, the indices for indoor air pollution include CO, $CO_2$, HCHO, nitrogen dioxide, ozone, fine dust ($PM_{10}$), volatile organic compounds, radon, asbestos and total bioaerosol[10]. In this study, CO, $CO_2$, HCHO and $PM_{10}$ were analyzed to assess indoor air quality in 9 kindergartens. Although CO and HCHO were within the normal range in all kindergartens, the $CO_2$ level was higher than the normal value in 3 kindergartens, and the $PM_{10}$ level was higher in 8 kindergartens. After the completion of the program for improving air quality, the $PM_{10}$ level dramatically decreased and the $PM_{10}$ level above the baseline value was detected only in 2 kindergartens. However, the $CO_2$ level demonstrated variable changes.

There have been only a few studies on the relationship between AD and indoor air pollution, although many studies on the relationship between asthma and indoor air

pollution have been found in the literature. Moon et al.[11] have demonstrated that the aldehyde level is not significantly different between houses of AD patients and control subjects. Hägerhed-Engman et al.[12] have indicated that there is a close relationship between indoor molds and AD. However, their result is questionable because the magnitude of molds was assessed using subjective odor, not an objective method. In our study, the EASI score decreased from 2.37 to 1.19 and the IGA score was improved, suggesting that indoor air quality improvement relieved symptoms of AD. After the completion of the program for improving indoor air quality, the frequency of hospital visits was the same as before in 10 of the 34 AD patients and lower than before in 15 AD patients. Nine AD patients did not take any medical services before and after the program. The mean number of hospital visits decreased from 1.3 to 0.7 per month in 15 AD patients with statistical significance. The mean value of EASI scores was low, which did not suggest an improvement of AD. The decrease of hospital visits could reflect the improvement of AD better rather than the EASI score.

PM means a mixture of solid particles and liquid droplets suspended in air. The definition of $PM_{10}$ is fine dust less than 10 $\mu$m in diameter, which is not filtered by oral and nasal mucous membranes and infiltrates deeply into the respiratory organs. $PM_{10}$ hinders lung function by sticking to the bronchus and pulmonary alveoli[13]. $PM_{10}$ includes harmful materials, such as sulphate, nitrate, acid and all sorts of heavy metal. It shows a very slow sedimentation rate; thus, it stays for a relatively long time in the air. Numerous studies on the toxic properties of PM in the human body have been carried out in the air pollution field[14]. Some previous studies have shown that PM in air pollution influences the aggravation of asthma attacks and chronic respiratory diseases[15,16]. It has been reported that PM increases tumor necrosis factor-$\alpha$ and interleulin (IL)-1$\beta$ in pulmonary alveoli mRNA of IL-1$\alpha$, IL-1$\beta$, IL-8 and granulocyte macrophage colony stimulating factor[17,18]. Increased amounts of proinflammatory cytokines contribute to the deterioration of chronic respiratory diseases as well as several skin diseases such as AD.

Due to the fact that fine dust between 10 to 30 $\mu$m carries dust mites[19], it can exacerbate the symptoms of AD. It has been documented that a high prevalence of AD is related to the environment with abundant fine dust[20,21]. In our study, symptoms of AD were improved by reducing the amount of $PM_{10}$.

$CO_2$ is a colorless and odorless gas. It is harmless in low density. High-density $CO_2$ in limited restricted indoor space indicates insufficient ventilation due to congested indoor harmful substances, namely, of the decreasing air quality. It is used as a representative index of indoor air quality[22]. Modern-style, highly sealed buildings without supplementary equipment for ventilation cannot provide fresh air; hence, the environmental quality of such living spaces is low, especially in long-term dwellings. $CO_2$ concentrations between 1,000 to 2,000 ppm can cause headache, hypertension, vomiting and fatigue in healthy adults and more severe symptoms in the elderly people and children. In our study, the indoor $CO_2$ level was higher than the baseline value. Subsequent to the completion of the program for improving air quality, the results varied from kindergarten to kindergarten. This may be due to different detection sites, such as classrooms, corridors and study rooms. Most study rooms indicated a higher $CO_2$ concentration than the baseline value due to a relatively large number of students in narrow space. Further, the program contents did not include ventilation by opening the windows and entrance doors in order to decrease the $CO_2$ concentration. The program for improving indoor air quality were conducted in 3 different methods; (1) removal of fine dust, spider web and mold spores in the wall and ceiling; (2) sterilization of desks, chairs and other teaching materials through steam heating after the removal of dust; and (3) reduction of fine dust, molds and dust mites through elimination of dust mites and floating matter as well as by steam cleaning the bedding. The program was designed to decrease amounts of fine dust and $CO_2$. After conducting the program, the $PM_{10}$ level decreased in all 9 kindergartens, while the $CO_2$ level showed variable results. This result may be attributed to different detection time, for example, school hours or between-classes-breaks, or before or after ventilation.

The prevalence of AD in 9 kindergartens located in Guro-gu, Seoul was 8%. The mean EASI score was 2.37 and the mean body surface area was 7.06%. After the completion of the program, the prevalence dropped to 7.6%, the mean EASI score decreased to 1.19, and the mean body surface area decreased to 4.22%. The IGA score also improved. The mean number of hospital visits also decreased from 1.3 to 0.7 per month in 15 patients. In conclusion, the results of this study suggest that the program for improving indoor air quality could improve the clinical symptoms and signs of AD as well as decrease the $PM_{10}$ level. Further studies on the relationship between AD and $PM_{10}$ level are needed in order to confirm our results.

## ACKNOWLEDGMENT

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