INTRODUCTION

Air pollution has been of great concern since the major industrial events associated with air pollution happened in Europe and the United States between the thirties and the fifties (1). Many studies have shown that air pollution is strongly associated with the human health, and the results of air pollution include an increased mortality rate (2-7), an increased number of patients with respiratory or cardiovascular diseases at outpatient departments or emergency rooms (8, 9), the aggravation of asthma (10-15), the increase of respiratory symptoms (16, 17) or the decrease of pulmonary function (18).

Particulate matter of a diameter under 10 μm (PM_{10}) is a mixture of solid and liquid particles in the air, and major sources of these fine particles are diesel engine exhaust, food cooking operations, and dust from wood burning (19). Particles derived from mobiles and stationary combustion sources are more likely to be in the respirable range. The decrease of peak expiratory flow (PEF) in children with asthma has been noted in those places where the density of traffic is heavy (13). 

Prior studies have found significant associations between concentrations of PM_{10} and decrements in pulmonary function test (PFT) values for in children with and without asthma (20, 21).

Recently, the number of traffic cars has been continuously increasing in Korea, and not surprisingly, the prevalence of asthma has also been increasing (22). We hypothesized that PM_{10}, which is mainly generated from automobiles, would have deleterious effects on the respiratory tract for even normal children. We also wanted to evaluate the effects of PM_{10} from the yellow dust storms on the lung function of children. This study was conducted to evaluate the effect of PM_{10} on the pulmonary function of normal Korean middle school children.
PM and Lung Function Test

The student subjects were excluded if they had respiratory symptoms within one week before the test and if they had a history of chronic respiratory disease including bronchial asthma and if their growth measurements (height and weight) were over the 97th percentile or below the 3rd percentile of Korean standard for their ages.

Methods

Pulmonary function testing was done using a portable electric mini-spirometer, in which forced expiratory volume per second (FEV₁) and forced vital capacity (FVC) were measured. Prior to pulmonary function testing, a detailed explanation was given to the subjects by the trained examiners. After the test was performed five times, the minimum and maximum values were discarded and the three remaining values were averaged. In March and December of 2000, pulmonary function testing was done repeatedly with the same students. We selected March as the month when the yellow dust storms mainly occurred to evaluate the effects of PM₁₀ on the lung function of healthy children. In addition, we also wanted to evaluate the effects of PM₁₀ generated mainly from automobiles, so we chose December, when the effects of both the yellow dust storms and ozone were minimal.

PM₁₀ data in the vicinity of two participating schools were obtained from the monthly reports of air quality from Korean Ministry of Environment in 2000 (23, 24).

Statistical analysis

Statistical analysis were done using SAS® version 6.12 for Windows, in which t-tests and the general linear model were used for univariate and multivariate analysis, respectively. A probability value of less than 0.05 was considered to be statistically significant.

RESULTS

Baseline level of PM₁₀ and other air pollutants

According to the data from the Korean Ministry of Environment in 2000 (23, 24), the mean values of monthly levels of PM₁₀ were 52.3 μg/m³ in Incheon and 55.8 μg/m³ in Ganghwa, and there was no significant difference between the two areas. In March, the mean values of PM₁₀ were the same as 64 μg/m³ in both areas. In December, the mean concentrations of PM₁₀ were 56 μg/m³ and 53 μg/m³ in Incheon and in Ganghwa, respectively, and no statistical significance was noted between the two areas. In both regions, however,
Table 4. Comparison of FEV1 values between March and December for each grade and gender of the study population

| Grade | Incheon | | Ganghwa | |
|-------|---------|------------------|------------------|
|       | Male    | Female           | Male             | Female           |
|       | March   | December         | March            | December         |
| First | 2.66±0.48 | 3.06±0.49*       | 2.57±0.16        | 2.65±0.22*       |
| Second| 2.91±0.54 | 3.28±0.52*       | 2.47±0.32        | 2.58±0.32*       |
| Third | 3.25±0.60 | 3.50±0.54*       | 2.64±0.28        | 2.78±0.39*       |

Table 5. Comparison of FVC values between March and December for each grade and gender of the study population

| Grade | Incheon | | Ganghwa | |
|-------|---------|------------------|------------------|
|       | Male    | Female           | Male             | Female           |
|       | March   | December         | March            | December         |
| First | 2.96±0.54 | 3.42±0.60*       | 2.76±0.26        | 2.77±0.25*       |
| Second| 3.14±0.66 | 3.59±0.62*       | 2.65±0.38        | 2.83±0.36*       |
| Third | 3.52±0.64 | 3.98±0.60*       | 2.75±0.28        | 2.90±0.44*       |

DISCUSSION

The prevalence of asthma has increased worldwide and this has been most strikingly observed in the industrialized countries during the last decade. Epidemiologic studies suggest that environmental factors including air pollution play an important role for the increasing prevalence of asthma. The major air pollutants are CO, NOx, O3, SO2 and particulate matters. Among these pollutants, PM10 can have easily access to the lung via the respiratory tract, and this matter can deposit within the lung (25). According to the study in Utah, U.S.A., during the winter when the level of PM10 was high, the number of patients with respiratory diseases was three times higher than that measured during the winter, when the level of PM10 was low since the steel factory workers went on a strike (26). Moreover, several investigators reported that not only have the number of patients at outpatient department or an emergency room increased, but also the hospitalized or expired patients increased on the days when atmospheric dust was prevalent (8, 9, 27). In Korea, the highest daily level of total suspended particles (TSP) was reported to be correlated with the number of hospitalization for asthma among the patients who were over 40 yr of age (15).

We thought that the levels of PM10 were higher in Incheon than in Ganghwa because the density of traffic is more serious in Incheon. Contrary to our expectations, the levels of PM10 were not statistically different between the two areas, although the levels of NOx and SO2 were higher in Incheon than in Ganghwa. The pulmonary functions of the students in two areas were not different either. Yet in both areas, the levels of PM10 were higher in March than in December.

The levels of PM10 often exceeded a 24-hr mean level of 150 μg/m3 for Korean environment air quality standards in March. These findings would be due to the yellow dust storms which refers to the wind-blown dust generated from northern China and Mongolia during the spring season. In Korea, yellow dust storms are usually observed in March and May every year, when the levels of PM10 exceeds the level of environmental standard by two or three times (28). The size of particulate matter from the yellow dust is mainly 3 μm (29). This range of particulate matter is easily respirable. So it is expected that this kind of particulate matter would have deleterious effects on respiratory system of normal children. Yellow dust storms occurred 4 times during March 2000 in Incheon and Ganghwa (30).

The present study showed that the values of FEV1 and FVC were greater in December than in March for both male and female students at all academic years. Even when taking into consideration the increase of the children's height and weight during the nine months period, the results of pulmonary function test in December were higher than those for the grades one year older, who were checked in March, for almost all grades. Because only the level of PM10 was significantly higher for March than for December in both areas, we suggest that the decrements of pulmonary function in March for both areas
are associated with the increased level of PM$_{10}$ and yellow dust. This particulate matter may have some important role for decrement of pulmonary function.

There are several limitations in this study including the lack of personal exposure data, the possibility of other air pollutant's effects, and lack of exact data of air pollutants on the day when the pulmonary function testing was performed. The levels of NO$_2$ and SO$_2$ were two times higher in Incheon than in Ganghwa and the levels of O$_3$ were higher in Ganghwa than in Incheon both for March and for December (Table 3). However, the levels of SO$_2$ and O$_3$ were similar in both May and December in each areas. The levels of NO$_2$ were higher for December than for March in both areas. Therefore, we believe that the decrements of the value of pulmonary function in March were caused by particulate matter.

In conclusion, we can suggest that PM$_{10}$, especially the particulate matter generated from yellow dust storms may have significant negative effects on the FVC and FEV$_1$ values in normal children.

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