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Effects of Particulate Matter (PM_{10}) on The Pulmonary Function of Middle-School Children

It has been reported that the particulate matter under 10 μm (PM_{10}) has deleterious effects on respiratory health. The purpose of this study was to assess the influence of PM_{10} upon normal children's lung function. The subjects were 368 middle school students in two areas of Incheon Metropolitan City. One (Incheon) is in the central city and the other (Ganghwa) is in the suburbs. Air pollution data in the vicinities of two participating schools were obtained from monthly report of air quality from Korean Ministry of Environment in 2000. Pulmonary function testing (PFT) was done two times, the first one in March and the second one in December with the same students. We analyzed the relationship between the PM_{10} levels and pulmonary functions (FEV_1, FVC) of the children. The monthly average of the PM_{10} level between the two areas showed no significant difference (55.3 vs. 52.3 μg/m^3). In both regions, the difference of the PM_{10} level between March and December was statistically significant (64 vs. 56 μg/m^3 in Incheon, 64 vs. 54 μg/m^3 in Ganghwa). The findings of the PFT values in March were significantly lower than those values found in December for both regions. In conclusion, we suggest that PM_{10} has some adverse effect on the pulmonary function of normal children.

Key Words : *Pneumoconiosis; Filtration; Particulate Matter (PM_{10}); Respiratory Function Tests*

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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.

MATERIALS AND METHODS

Subjects

We assumed that middle-school students are more apt to undergo the pulmonary function test and present accurate results, therefore we randomly selected middle school students from two areas of Incheon Metropolitan City; one area is in the central city (Incheon) where the traffic is heavy and the other area is in a suburb (Ganghwa). We randomly selected a few classes in each grade in a school, and the number of students was 124 (male; 75, female; 49) from Incheon and

Table 1. Number of study subjects

Grade	Incheon		Ganghwa	
	Male	Female	Male	Female
First	26	16	43	43
Second	19	21	41	39
Third	30	12	41	37
Total	75	49	125	119

Table 2. Monthly mean concentration of PM_{10} ($\mu g/m^3$) for Incheon and Ganghwa in 2000

Month	Incheon	Ganghwa
January	47	48
February	51	50
March	64	64
April	62	75
May	53	51
June	58	68
July	56	55
August	30	38
September	40	48
October	53	52
November	58	63
December	56	53

*Reference (30).

244 (male; 125, female; 119) from Ganghwa (Table 1). 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 3th 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 (FEV_1) 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 PM_{10} on the lung function of healthy children. In addition, we also wanted to evaluate the effects of PM_{10} generated mainly from automobiles, so we chose December, when the effects of both the yellow dust storms and ozone were minimal.

PM_{10} 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).

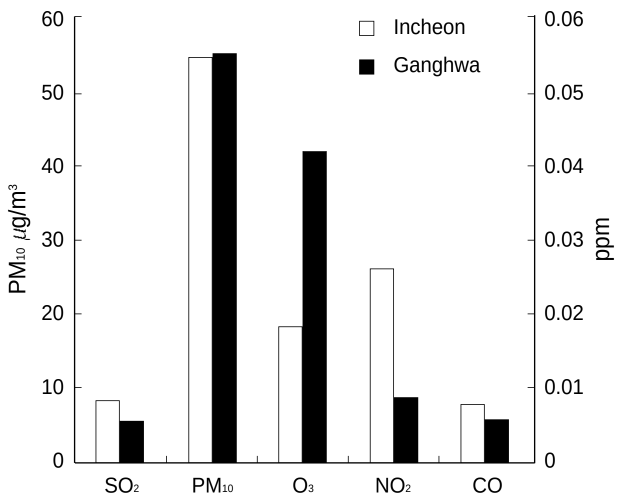

Fig. 1. Annual mean concentration of major pollutants for Incheon and Ganghwa during the study period. *Reference (30).

Table 3. Mean concentration of major pollutants in March and in December for the two areas

Air pollutants	Incheon		Ganghwa	
	March	December	March	December
PM_{10} ($\mu g/m^3$)	64	54*	64	53*
O_3 (ppm)	0.018	0.016	0.048†	0.035†
NO_2 (ppm)	0.028	0.043*	0.006†	0.015*†
SO_2 (ppm)	0.012	0.013	0.005†	0.006†

*Statistical difference was noted for the levels of air pollutants between March and December ($p<0.05$). †Statistical difference was noted for the levels of air pollutants between Incheon and Kangwha ($p<0.05$). ‡Reference (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 PM_{10} 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 PM_{10} were 52.3 $\mu g/m^3$ in Incheon and 55.8 $\mu g/m^3$ in Ganghwa, and there was no significant difference between the two areas. In March, the mean values of PM_{10} were the same as 64 $\mu g/m^3$ in both areas. In December, the mean concentrations of PM_{10} were 56 $\mu g/m^3$ and 53 $\mu g/m^3$ in Incheon and in Ganghwa, respectively, and no statistical significance was noted between the two areas. In both regions, however,

Table 4. Comparison of FEV_1 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	March	December	March	December
First	2.66±0.48	3.06±0.49*	2.57±0.16	2.65±0.22*	2.54±0.53	2.91±0.62*	2.49±0.28	2.63±0.32*
Second	2.91±0.54	3.28±0.52*	2.47±0.32	2.58±0.32*	2.93±0.53	3.33±0.57*	2.51±0.29	2.59±0.24*
Third	3.25±0.60	3.50±0.54*	2.64±0.28	2.78±0.39*	3.31±0.40	3.57±0.33*	2.76±0.31	2.79±0.33

*p<0.05.

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	March	December	March	December
First	2.96±0.54	3.42±0.60*	2.76±0.26	2.77±0.25*	2.84±0.55	3.21±0.63*	2.66±0.33	2.88±0.40*
Second	3.14±0.65	3.59±0.62*	2.65±0.38	2.83±0.36*	3.27±0.61	3.74±0.62*	2.60±0.32	2.80±0.32*
Third	3.52±0.64	3.98±0.60*	2.75±0.28	2.90±0.44*	3.69±0.51	4.00±0.44*	2.89±0.33	3.02±0.38*

*p<0.05.

the levels of PM_{10} were higher in March than in December (Table 2). The mean levels of NO_2 and SO_2 were higher in Incheon than in Ganghwa, but the mean levels of O_3 were higher in Ganghwa than in Incheon (Fig. 1, Table 3).

The results of pulmonary function test

In both regions, the higher academic year was, the greater the FEV_1 and FVC values were. Moreover, the FEV_1 and FVC values were greater in male students than in female students during the same academic year. The FEV_1 and FVC value were greater in December than in March for the same academic year in both areas (Table 4, 5).

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, NO_x, O_3, SO_2 and particulate matters. Among these pollutants, PM_{10} 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 PM_{10} was high, the number of patients with respiratory diseases was three times higher than that measured during the winter, when the level of PM_{10} 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 PM_{10} were higher in Incheon than in Ganghwa because the density of traffic is more serious in Incheon. Contrary to our expectations, the levels of PM_{10} were not statistically different between the two areas, although the levels of NO_2 and SO_2 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 PM_{10} were higher in March than in December.

The levels of PM_{10} often exceeded a 24-hr mean level of 150 $\mu m/m^3$ 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 level of PM_{10} 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 FEV_1 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 PM_{10} 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 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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