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[원 저]

Burden of Disease Due to Outdoor Air Pollution in Korea: Based on PM_{10}

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ABSTRACT

Purpose: This study measured the burden of disease in Korea related to outdoor air pollution using disability-adjusted life year (DALY).

Materials and Methods: As a risk factor of outdoor air pollution, particulate matter with a diameter less than 10 μm(PM_{10}) was used. First, PM_{10}-related diseases and their relative risk (RR) were selected by means of a literature review. Second, population attributable fractions were computed by using formulae including RR and population exposure to PM_{10}. Third, DALYs of PM_{10}-related diseases in Korea were estimated. Finally, the attributable burden of disease due to PM_{10} was measured as the sum of the products that multiplied the DALYs of PM_{10}-related diseases by their population attributable fractions.

Results: The disease burden of PM_{10} was 6.9 DALY per 1,000 persons in 2007. The attributable burden of PM_{10} was 2.68 for lung cancer, 2.41 for COPD, 0.62 for ischemic heart disease, 0.61 for pneumonia, 0.55 for asthma, and 0.03 for preterm.

Conclusions: This study showed the environmental burden of disease of PM_{10} and burden of PM_{10}-related disease through objective data. It also suggested that active efforts are needed to continuously measure and reduce the burden of environmental diseases in Korea.

Key words: Outdoor air pollution, PM_{10}, Disability adjusted life year (DALY), Burden of disease

I. Introduction

In 2006, WHO suggested modifiable environments with eight categories which could be prevented among risk factors that cause environmental disease and measured environmental burden of disease (EBD) with disability-adjusted life year (DALY). Korea ranked 51th (192 countries) with 23 DALY per 1,000 cap. and more precisely, the estimates of burden of outdoor air pollution using PM_{10} was 0.9 DALY per 1,000 cap. in 2006. However the WHO study has limitation that DALY is estimated by applying the PM_{10} levels of the urban areas with populations greater than 100,000 and using common exposure rates by dividing into six regions, not by specific countries. In addition, the WHO study used several collected information on which sources were inaccurate or not suitable in measuring the incidence and the mortality rate.[1,2)]

Therefore, this study was intended to measure the burden of disease of outdoor air pollution (especially PM_{10}) using DALY in Korea, by means of the

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method that the WHO and GBD (Global Burden of Disease) group suggested.

II. Materials and Methods

1. Study data

To measure the burden of disease of particulate matter, exposure data of PM_{10}, relative risks necessary to present correlation between PM_{10} and each disease, and data to calculate DALY of PM_{10}-related diseases were used.

2. Exposure data of PM_{10}

In this study, among 5 air pollutants whose emission amounts were obtained from the National Institute of Environmental Research (NIER) of the Ministry of Environment, PM_{10} was used as exposure index, which is frequently used for air pollution epidemiology studies and has significant effects on human body.

For the PM_{10} data, the measured values of 394 monitoring stations in 83 'city' and 'county' around the nation were applied according to the trend transition table of the air pollution levels which is presented in the Annual Report of Ambient Air Quality in Korea (2007), published by the NIER every year.[3)]

3. Data for choosing relative risk of PM_{10}-related diseases

To select PM_{10}-related diseases and to express the relationship between PM_{10} and each disease, the relative risk, which is necessary to calculate the attributable risk, was chosen through literature review.

4. Data for measuring the burden of the PM_{10}-related diseases

To consider the burden of PM_{10}-related diseases, the statistics of the cause of death obtained from the Korea National Statistical Office (KNSO) and life table of KNSO were investigated.[4)] In addition, to obtain incidence rate, data on health care utilization for diseases related to PM_{10} from Health Insurance Review Agency (HIRA) for 2004~2007 was used.

III. Methods

1. PM_{10}-related diseases and relative risks

To review articles, an electronic data base (DB) search was conducted by dividing criteria into foreign and domestic, where PUBMED and National Assembly Library of Korea, KoreaMed and Kmbase were used for foreign and domestic articles respectively. The papers searched were published from January 1, 1990 to November, 2008. For disease selection, the categories of diseases due to outdoor air pollution presented in EBD studies were utilized. PM_{10}-related diseases and relative risks are divided into categories such as respiratory diseases, perinatal conditions, congenital abnormalities, neoplasm, cardiovascular diseases, COPD and asthma in EBD studies.[5)] When domestic articles were searched, major search words included "outdoor air pollution" and "PM_{10}". Secondarily, a manual search was performed using references from DB searched papers to select further articles for use in this study.

Criteria for selection of literature regarding PM_{10}-related diseases were as follows. Firstly, an article should highlight diseases caused by PM_{10} and demonstrate their relative risk. Secondly, our study design included the ecological study, case series study and time series study which present the correlations of change patterns between the specific diseases as well as the cohort study. Thirdly, when various studies were found according to diseases, a cohort study was selected first. In the case where there was no cohort study on a disease, an ecological study and time series study were chosen. In addition, among studies with same study design, studies recruiting Koreans or Asians as subjects were selected. After selecting only diseases with a

Table 1. PM_{10}-related diseases and its relative risks

Disease		Exposure level	Relative risks	95% Confidence Interval
Lung cancer[6]	male	51.24 μg/m³	3.36	(1.57-7.19)
	female	51.24 μg/m³	1.33	(0.60-2.96)
Coronary heart disease[7]		21.00 μg/m³	1.43	(1.10-1.86)
Low birth weight[8]		50.00 μg/m³	1.33	(1.02-1.74)
Preterm[9]		64.56 μg/m³	1.27	(1.04-1.56)
Pneumonia[10]		45.00 μg/m³	1.19	(1.07-1.32)
Sudden infant death syndrome[11]		28.40 μg/m³	1.12	(1.07-1.17)
Asthma[12]		60.00 μg/m³	1.11	(1.03-1.19)
Still birth[13]		89.10 μg/m³	1.09	(1.04-1.15)
Chronic bronchitis[14]		50.00 μg/m³	1.05	(1.015-1.077)
COPD[15]		51.53 μg/m³	1.02	(1.006-1.041)
Ischemic heart disease[15]		51.53 μg/m³	1.01	(1.001-1.025)

causal relation through literature review, 35 papers were selected finally. The PM_{10}-related diseases were categorized into neoplasm, infant related diseases, respiratory diseases and cardiovascular diseases. As only a paper on lung cancer was shown by separating into males and females, relative risk of lung cancer is presented by dividing gender. Also, the relative risk of lung cancer for female showed no statistically significant (RR 1.33, 95% CI 0.60~2.96). However, we adopted this RR to calculate the burden of disease due to the inadequacy of data (Table 1).

2. Calculating population exposure due to PM_{10} and attributable risk

To calculate population exposure (Pe) of a population, the resident registered population (2007) from KNSO according to 'city' and 'county' were used and measured values of 394 stations in 83 city and county around the nation were applied. The exposure level of air pollution was an annual average based on the data from the Air Quality Research Division of NIER, and when two or more measurement points for automatic air quality monitoring were located in city or county, their average was used. In the case where there was no point for automatic air quality monitoring in city or county, PM_{10} level was assumed to be less than the average annual criterion of Korea (50 μg/m³).

Table 2. Exposure difference and attributable fraction

Disease	Exposure difference (Unit: μg/m³)	Attributable fraction (%)
Lung cancer	50	29.1
	51-75	69.70
	76-100	1.15
Ischemic heart disease	50	29.1
	51-60	32.76
	61-70	35.1
	71-80	2.99
COPD	51	32.2
	52-61	34.43
	62-71	30.34
	72-81	2.99
Pneumonia	45	18.55
	46-145	81.45
Asthma	60	61.89
	61-92.6	38.11
Preterm	64.56	83.01
	64.57-106.39	16.98

Out of the total population of Korea (49,268,928 persons) in 2007, 7,942,731 lived in city and county without the point for automatic air quality monitoring. The comparative risk of residents in exposed areas according to exposure level was calculated based on a multiplicative model as the level of surpassing

exposure criterion point (Table 2).[16]

Population Attributable Fractions (PAF) was defined by how much percent of incidence of the disease are caused by exposure to health risk factor. Therefore attributable burden of health risk factor was measured by multiplying DALY of each disease with PAF (Table 3).

3. Measuring DALY of PM_{10}-related diseases

DALY was calculated by adding years of Life Lost (YLL) due to premature death and years lived with disability (YLD) due to disability.

DALY = YLL + YLD

4. Measuring YLL due to PM_{10}-related diseases

Firstly, with the data on death causes from KNSO and life table (KNSO) in 2007, standardized life expectancy according to age, gender and causes of the death were investigated[4]. Secondly, to calculate the years of life lost due to premature mortality by age group, Standard Expected Years of Life Lost (SEYLL) was used. Thirdly, this study applying the estimated variables to the formula that estimates the years of life lost due to premature mortality, calculated burden of disease due to premature death.[17]

5. Measuring the YLD due to PM_{10}-related diseases

Incidence rate of diseases related to PM_{10} was calculated using the insurance claim data from HIRA for 2004~2007. To calculate fatality rate, the number of deaths was investigated using the data on death causes of KNSO in 2007, and the average age at disease onset and the morbidity period except remission rate were calculated using the DISMOD II model. And this study used Korean disability weights to reflect to precise condition of Korean patients[18].

6. Measuring the attributable burden of PM_{10}-related diseases

To measure attributable burden of PM_{10}, values multiplying DALY of each disease with PAF, meaning how much percent of occurrences of the disease are caused by exposure to PM_{10}, were added.

Attributable burden = DALY × PAF

IV. Results

1. Attributable burden of PM_{10}

Comparison of these results according to PM_{10}-related diseases and gender was presented in Table 4.

The burden of disease attributable to PM_{10} measured by DALY was 6.9 (unit: DALY per 1,000 persons) in 2007. Attributable burden of lung cancer was the highest, 2.68 (38.9%), and COPD followed it by 2.41 (34.9%). Ischemic heart disease, pneumonia, asthma and preterm recorded 0.62 (9%), 0.61 (8.8%),

Table 3. Population attributable fractions of PM_{10}-related disease

Disease		PAF
Lung cancer	male	0.6837
	female	0.2057
Ischemic heart disease		0.3265
COPD		0.3024
Pneumonia		0.1340
Asthma		0.1319
Preterm		0.0679

Table 4. Attributable burden of diseases by PM_{10} in Korea (unit: DALY/1,000 cap. in 2007)

Disease	Outdoor air pollution		
	Total (%)	Male (%)	Female (%)
Lung Cancer	2.68 (38.9)	2.42 (48.2)	0.26 (13.8)
COPD	2.41 (34.9)	1.51 (30.1)	0.90 (47.7)
Ischemic Heart Disease	0.62 (9)	0.38 (7.6)	0.24 (12.7)
Pneumonia	0.61 (8.8)	0.36 (7.2)	0.25 (13.3)
Asthma	0.55 (8)	0.33 (6.6)	0.22 (11.7)
Preterm	0.03 (0.4)	0.013 (0.3)	0.015 (0.8)
Total	6.9 (100)	5.01 (100)	1.89 (100)

Table 5. Attributable burden of diseases due to outdoor air pollution in men according to age group

(unit: DALY/1,000 cap. in 2007)

	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
Asthma	0.067	0.016	0.006	0.018	0.056	0.058	0.059	0.038	0.009	0.000
COPD	0.050	0.031	0.024	0.059	0.314	0.351	0.353	0.250	0.074	0.003
Lung Cancer	0.000	0.003	0.008	0.045	0.220	0.523	0.880	0.623	0.111	0.002
Pneumonia	0.062	0.01	0.009	0.045	0.071	0.054	0.050	0.042	0.017	0.001
Ischemic Heart Disease	0.000	0.001	0.005	0.026	0.084	0.119	0.095	0.042	0.006	0.000
Preterm	0.009	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 6. Attributable burden of diseases due to outdoor air pollution in women according to age group

(unit: DALY/1,000 cap. in 2007)

	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
Asthma	0.056	0.009	0.007	0.015	0.015	0.012	0.032	0.052	0.019	0.001
COPD	0.047	0.015	0.044	0.075	0.071	0.093	0.242	0.210	0.088	0.007
Lung Cancer	0.000	0.000	0.003	0.014	0.034	0.051	0.064	0.070	0.026	0.003
Pneumonia	0.050	0.008	0.008	0.010	0.012	0.018	0.043	0.058	0.037	0.005
Ischemic Heart Disease	0.000	0.001	0.002	0.006	0.033	0.062	0.074	0.048	0.013	0.001
Preterm	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

0.55 (8%) and 0.03 (0.4%), respectively.

In males, PM_{10}-attributable burden of the diseases was lung cancer (48.2%), COPD (30.1%), ischemic heart disease (7.6%), pneumonia (7.2%) and asthma (6.6%) respectively in that order. For women, COPD (47.7%) showed the largest burden and lung cancer (13.8%), pneumonia (13.3%), ischemic heart disease (12.7%) and asthma (11.7%) followed it in that order.

2. Attributable burden according to PM_{10}-related diseases, gender and age

According to the results of attributable burden based on age, the burden of asthma as well as pneumonia were higher among infants and children aged less than 10 years in both males and females and they tended to decline after the ages. The burden of premature birth among infant-related diseases accounted for a relatively small portion, at 0.4% of the total burden of diseases caused by PM_{10}. However, it was present only under the age of 10 and the burden value was larger in female infants than in male infants.

Attributable burden of COPD was the largest in the 20s age group and its burden showed high levels at 30s and at 40s in males and females, respectively. Among the 50s age group in males, the attributable burden of lung cancer was highest and the burden of males skyrocketed after 40s. For females, the burden of COPD, and ischemic heart disease were at high levels among the 50s age group. The burden of lung cancer reached its highest level in the 60s men's age group but it reduced over-70 age group. For 60s females' age group, it showed a similar tendency starting at the 50s age group (Table 5, 6).

V. Discussion

This study estimated attributable burden of PM_{10} among the outdoor air pollutants by using measurement indicator DALY, and the total burden

was 6.9 (unit: DALY/1000 persons) in 2007. Measurement of attributable burden caused by PM_{10} found that the burden was larger in males than in females overall. For men, lung cancer and COPD were the highest burden of disease. And COPD, ischemic heart disease accounted for largest portion in females.

However, this result can be considered that there are significant differences from Korea's attributable burden (0.9 DALY/1,000 cap.) due to outdoor air pollution measured by WHO in 2006. The main causes for those differences are the fact that the urban areas, targeted to estimate exposure level of outdoor air pollution, were not around nation but those with population over 100,000.

The applied average level of PM_{10} was 43 μg/m³ in 2004. Thus this result was estimated to be less than 50 μg/m³, the Korea's average level of PM_{10} in 2007. In addition, this study used literature review to calculate relative risk of PM_{10} and domestic epidemiological data such as mortality, incidence, and prevalence rate were used. In the case of EBD study, mortality rate was used by specific countries such as Korea. However data such as prevalence, incidence rate were applied only by 14 subregions, not by specific countries. Therefore EBD results of WHO are thought to be underestimated comparing those of this study.

A study on the burden of disease due to PM_{10} of the outdoor air pollutants in South Africa calculated only YLL by using PM_{10}, $PM_{2.5,}$ thus it was not able to directly compare the size of the burden of disease.[19] In males, YLL were ischemic heart disease (5,694), stroke (4,479), lung cancer (2,449), COPD (2,385) and in females, YLL was stroke (6,144), ischemic heart disease (4,088), hypertensive disease (3,239), COPD (1,415). Therefore the burden of high mortality rate disease was bigger than high morbidity rate disease, which was slightly different from the result of this study. In addition, considering the other studies on burden of disease of Korean people in 2005, the burden of disease attributable to smoking was 271.78 for males and 72.67 for females (unit: DALY/1,000 cap). Attributable burden of smoking in males was pneumonia & influenza (71.974), ischemic heart disease (23.66), trachea/lung/bronchus cancer (4.809), chronic airways obstruction (3.18) and attributable burden of smoking in females were pneumonia & influenza (12.657), ischemic heart disease (3.691), chronic airways obstruction (1.246), trachea/lung/bronchus cancer (0.966).[20] Thus it showed that the burden of disease due to smoking is bigger than the burden of disease due to outdoor air pollution.

From results on attributable burden of PM_{10} according to gender, lung cancer accounted for the largest portion, 48.2% of the total burden of air pollution in males. Currently, the most well-known factor for causing lung cancer is smoking[20]. And according to a study that measured the burden of disease of Koreans in 2002, the burden of trachea, lung, and bronchus cancer due to smoking accounted for 4.81 in males, 0.966 in females (unit: DALY/1,000 cap).[20] However exposure to radon and occupational materials such as arsenic and asbestos and air pollution has reported to increase the incidence of lung cancer, except smoking.[21,22] Therefore air pollution is associated with increased incidence of lung cancer and policies for improvement of air quality to decrease PM_{10} are thought to be performed continuously.

In our study what ranked second in attributable burden of PM_{10} in males was COPD and it accounted for 30.1% of the total burden. Moreover, it showed the largest level in females by recording 47.7% of the total burden of females. These results are similar with epidemiological reports on COPD and prevalence and mortality rates of COPD have grown steadily in mainly developed countries.[23] High smoking rate in the past and an astonishing increase of aged population are considered to be the main contributing causes. Because COPD tends to be diagnosed in smokers in their 40s or 50s with a history of smoking, the tendency is same with the

result of this study that AB-PM_{10} was increased at 40s in comparison according to age.[24]

For females, the weight of COPD in the total burden was less than that of males by recording 47.7% and lung cancer, pneumonia, ischemic heart disease and asthma except COPD showed similar weights with men.

When the burden of disease was compared to age, the burden of asthma and pneumonia was large in infants and children aged less than 10 years in both of males and females, tended to decrease after that time and then increased again. This result is same with epidemiological surveys on air pollution performed by restricting subjects to children[25-27] and the higher burden is observed because during the time respiratory organs form, their respiratory rate is higher than adults and they are outside longer to be exposed to air pollution for a long time.[28]

However, materials and method used in this study had following limitations. First, in using articles showing a causal relation between PM_{10} and a disease, the studies on cardiovascular and respiratory diseases and neoplasm, except for infant-related diseases, were conducted in foreign countries. Although epidemiological studies on air pollution performed in Korea also investigated respiratory and cardiovascular diseases, death, asthma and allergy, they did not meet inclusion criteria of this study. An epidemiological survey on impact of air pollution on delivery was performed first in Korea in around 2000 and some research reported that air pollution was related with the risk of delivery of underweighted newborn infants. Based on the results the PAF of infant-related diseases was calculated by using domestic data.[29] In addition, the studies on cardiovascular and lung diseases used in this study were conducted with Asians as their subjects rather than others who showed different patterns of diseases. For other diseases except them mentioned above, we tried to search studies performed with Asians as subjects but we could not find any one by limiting a risk factor to PM_{10} although there was some research on correlation between increasing incidence of lung cancer and indoor air pollution (use of fossil fuel), radon and environmental tobacco smoking. More epidemiological studies on air pollution related diseases with Koreans are needed to be conducted in the future.

Second, this study chose papers with larger-scaled study design and domestic papers to determine PAF among several searched articles. However, examining relative risk through systemic review as suggested in GBD methodology or estimating overall or average impact (pooled RR) through meta-analysis for papers presenting relative risks are considered to be more reliable. In addition, as each paper has different exposure criteria in evaluating the attributable risk of a risk factor, a method of measuring it with a standard of air pollution criterion of WHO (annual average of 20 $\mu g/m^3$) or that of Korea (50 $\mu g/m^3$) is necessary.

Lastly, this study examined only PM_{10} as a risk factor to assess attributable burden due to outdoor air pollution. However it is necessary to consider that also $PM_{2.5}$ and gaseous materials (NOx, SOx, CO, O_3, etc.) should be evaluated as risk factors of air pollution to calculate more accurate burden of disease.

This study suggested that the environmental burden of disease of PM_{10} by using domestic data. These estimates showed the range of air pollution problems out of environmental pollution ones and proposed prediction needed politically. Therefore air pollution control should be conducted first compared to other interventions to promote public health and active efforts are needed to measure and reduce the burden of environmental disease continuously in Korea.

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