RESEARCH ARTICLE

Correlation of Breast Cancer Incidence with the Number of Motor Vehicles and Consumption of Gasoline in Korea

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Abstract

While several reproductive and lifestyle-related factors are already well-known as established risk factors for breast cancer, environmental factors have attracted attention only recently. The objective of the current study was to assess the association between the breast cancer incidences in females, the mortality rate and the number of motor vehicles on the one side and the consumption of gasoline which could work as a major source of air pollution at the other side. The breast cancer incidences and the mortality trends were compared with various indices of westernization like dietary patterns or industrialization with 10 years lag of time. Geographical variations with 10, 15 and 20 years lag of time were assessed between the breast cancer incidence in 2010 and the number of motor vehicles as well as the consumption of gasoline. The upward trend of motor vehicle numbers proved to be comparable to those of breast cancer incidence and mortality. However, the consumption of gasoline started to decrease since the mid-1990s. The geographic distribution of motor vehicle numbers and gasoline consumption in 1990 is in a positive correlation with the breast cancer incidence rates in 2010 and the 20-year lag time (R^2 0.379 with the number of motor vehicles and 0.345 with consumption of gasoline). In a linear relationship between the breast cancer incidences in 2010 and the log transformed number of motor vehicles, the log transformed consumption of gasoline in 2000 also showed a positive relationship (R^2 0.367 with the number of motor vehicles and 0.329 with consumption of gasoline). The results of the current study indicate that there may be a positive relation between the number of vehicles, gasoline consumption and the incidence of breast cancer from the aspects of long-term trends and geographical variation.

Keywords: Breast cancer - environmental factor - traffic emission - motor vehicle - consumption of gasoline

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Introduction

Breast cancer is the most frequently incident cancer and the most common cause of cancer death among women. In 2008, 1.38 million new breast cancer cases were diagnosed and 458 thousand of deaths due to breast cancer occurred worldwide. Breast cancer is the most common cancer in developed as well as in developing countries actually. But the incidence rate was much higher in the developed countries compared with the developing countries (Ferlay et al., 2010).

Breast cancer is the second most common cancer among women in Korea. The incidence of breast cancer is rapidly increasing with 6.3% annual percent increase. 14,208 new female breast cancer cases were developed and 1,858 women died because of this disease in Korea (Jung et al., 2013). Several reproductive and life style related factors such as diet and anthropometry as well as hereditary factors are well known as risk factors (Key et al., 2001). However, these well-known risk factors were attributed to less than 50% of breast cancer cases only (Madigan et al., 1995; Coyle, 2004). Therefore, efforts to investigate other risk factors of breast cancer have been made during the last time.

In the developing countries, there has been a rapid increase in the incidence and burden of breast cancer (Porter, 2009). It might be attributed to an adoption of western life style such as increased intake of high calorie food, meat or fat (Kim et al., 2009) as well as physical inactivity and changes in reproductive factors such as

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a later age at first full term pregnancy and a smaller birth rate per woman (Ferlay et al., 2010; Jemal et al., 2010). In addition, the industrialization and its related environmental pollutions may be suggested as risk factors for increased breast cancer incidents (Nie et al., 2007), under the consideration of a higher risk of breast cancer in the developed countries (Bray et al., 2004; Ferlay et al., 2010) and the urban areas (compared to the rural area) of industrialized nations (Blot et al., 1977; Nasca et al., 1992). Among the industrialization reflecting variables, traffic emissions which include many kinds of carcinogens are the major source of air pollution in urban areas (Chen and Bina, 2012; Nie et al., 2007).

Considering there is a remarkable difference in the traffic emission level according to geographic regions, to estimate the traffic emission at a regional level will be necessary. Therefore the number of motor vehicles and the amount of gasoline consumption which has been generally used as motor vehicle fuel were collected as indicators of traffic emission. Gasoline contains more than 150 chemicals including small amounts of benzene, toluene, xylene and sometimes lead (ATSDR, 1995). Although there is no evidence that an exposure to gasoline causes cancer in humans, the included materials such as benzene and several antiknocking additives are carcinogenic (ATSDR, 1995). Therefore, in this study the long term trend between the incidence of breast cancer in woman, the mortality trends and various westernization indices like dietary pattern or industrialization were investigated. Among them, the focus was set on the association between female breast cancer incidents, the mortality rate and the number of motor vehicles with their consumption of gasoline which could work as a major air pollution source. Also, it was investigated whether geographical variations of breast cancer incidents showed a relationship with the number of motor vehicles and consumption of gasoline or not.

Materials and Methods

Breast cancer incidence and mortality data

Breast cancer incidence data were obtained from the Korea Central Cancer Registry (KCCR). In the KCCR, both nationwide and regional cancer incidence data have been collected since 1999 annually. The breast cancer mortality rates from 1983 to 2010 were obtained from the Korean Statistical Information Service website (KOSIS, www.kosis.kr). Both the long term age-adjusted incidents and the mortality rates for breast cancer were calculated using the direct standardization method. For this the population in mid2000 was used as a standard population. The geographic variations of breast cancer incidents in 2010 were adjusted using the direct standardization method using the world standard population (Segi, 1960).

Data for indices of westernization of dietary pattern or industrialization

For this study a number of indices of westernization of dietary pattern or industrialization were selected which were available at the national level statistics with 10 years or more lag time. The number of registered motor vehicle which was collected since 1966 by the Ministry of Land, Infrastructure and Transport (Ministry of Land, Infrastructure and Transport), the total waste amount, the total industrial waste amount and the total incinerated waste amount which was collected since 1990 or 1992 by the Ministry of Environment (Ministry of Environment) (Woitas-Slubowska et al., 2010), the total daily product consumption, the total meat and milk consumption per person which was available since 1978 and 2005 by the Statistics Korea (Ministry of Agriculture, Food and Riral Affairs), and the total agricultural pesticides production which was available since 1995 by the Statistics Korea (Statistics Korea) were accessed.

Data for number of motor vehicle and gasoline consumption

National and regional data regarding the number of registered motor vehicles were obtained from the KOSIS of the Statistics Korea (Ministry of Land, Infrastructure and Transport). The national data regarding the number of motor vehicles were collected since 1966 by the Ministry of Land, Infrastructure and Transport (Korea Energy Economics Institute)(Schroder et al., 2004). After 1980, regional data for 11 regions among 16 provinces were available. Later on, data about the other 5 regions' data were available one by one and the data of all 16 provinces were available since 1997. The data about the national consumption of gasoline were available for 1968 to 2007 and regional data were available since 1990.

Statistical analysis

Breast cancer incidence and mortality trends with various indices of westernization of dietary pattern or industrialization with 10 years of lag time considering the induction period of cancer were compared using the Pearson correlation analysis. The geographic pattern between the female breast cancer incidence and the number of motor vehicles, the consumption of gasoline in 16 Korean provinces were examined with 10, 15and 20 year time lags. Only the incidence data were used because incidence is more related to the etiological causes. The number of breast cancer incidence in 2010 and the number of motor vehicles and consumption of gasoline in 1990, 1995 and in 2000 were used. A linear regression was applied to estimate the relationship between the incidences of 16 different provinces and the number of motor vehicles with their consumption of gasoline. A coefficient of determination (R-squared) and p value was presented for the number of motor vehicles and consumption of gasoline in 1990, 1995 and 2000. The log linear relationship with R-squared between the breast cancer incidents in 2010 and a log transformation of the number of motor vehicles and the consumption of gasoline in 2000 was illustrated using the simple linear regression analysis.

Results

Table 1 shows the correlation coefficients between breast cancer incidence, mortality and indices of westernization of dietary pattern or industrialization. Among the selected factors, the number of registered motor vehicles and total daily product consumption could

Table 1. The Correlation Coefficients[1] Between Breast Cancer Incidence, Mortality And Indices of Westernization of Dietary Pattern or Industrialization with 10 Year Lag Time

Index	Breast cancer incidence[2]	Breast cancer mortality[2]
Number of registered motor vehicles (x 10,000), 1966-2009	0.99*	0.92*
Total daily product consumption, (Ton), 1978-2008	0.90*	0.92*
Total meat consumption per person, (Kg), 1995-2008	0.99*	0.99*
Total milk consumption per person, (Kg), 1995-2008	0.91*	0.92*
Total agricultural pesticides production, (M/T), 1995-2009	0.75	-0.3
Total waste, (Ton), 1995-2010	0.96*	0.74
Total industrial waste, (Ton), 1995-2010	0.99*	0.84*
Total incinerated waste, (Ton), 1995-2011	0.80*	0.76

*P-value <0.05; [1]Correlation coefficient calculated by the Pearson correlation analysis; [2]Per 100,000 persons; [3]Cannot calculated due to lack of old data

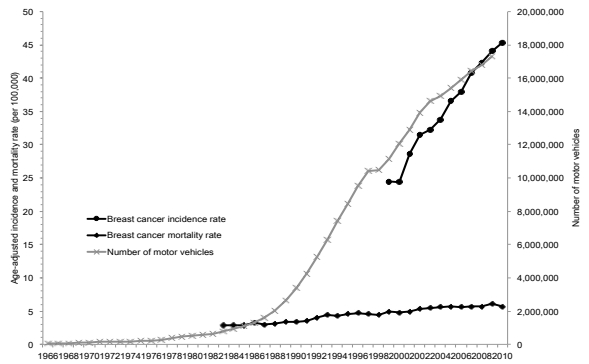

Figure 1. Number of Motor Vehicles and the Incidence and Mortality Rate of Breast Cancer, Republic of Korea

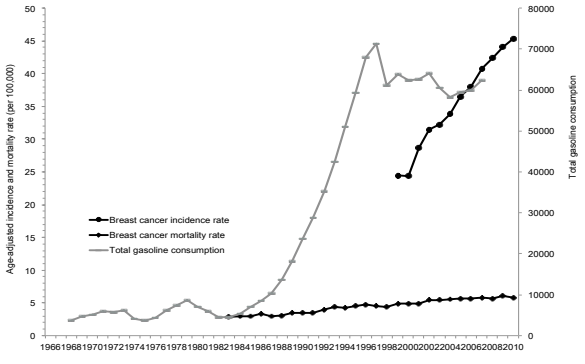

Figure 2. Consumption of Gasoline and the Incidence and Mortality Rate of Breast Cancer, Republic of Korea

Table 2. Number and Correlations between Motor Vehicles, Consumption of Gasoline and Breast cancer Incidence Rates of 16 Provinces

Region	Number of motor vehicles[1]			Consumption of gasoline			Female breast cancer	
	1990	1995	2000	1990	1995	2000	Number of cases	Standardized incidence[2]
Seoul	119	204	244	8,227	14,052	13,183	3,478	46.7
Busan	29	60	81	1,521	3,403	3,820	1,116	40.5
Daegu	-	52	69	895	2,708	2,813	737	39.9
Incheon	15	44	65	539	1,572	1,670	822	43.3
Gwangju	8	23	34	1,378	3,385	3,491	377	38.8
Daejeon	9	26	38	-	-	1,751	432	41.7
Ulsan	-	-	29	515	1,545	1,172	295	37.6
Gyeonggi-do	45	155	249	3,452	11,739	13,845	3,314	42.2
Gangwon-do	9	28	42	752	2,372	2,482	399	36
Chungcheongbuk-do	8	26	39	817	2,254	2,132	374	34.7
Chungcheongnam-do	10	30	49	938	2,095	2,731	487	35.1
Jeollabuk-do	10	32	48	821	2,398	2,447	471	34.9
Jeollanam-do	10	29	47	626	1,845	1,635	423	32.2
Gyeongsangbuk-do	17	52	75	1,256	4,108	4,214	614	30.9
Gyeongsangnam-do	25	74	80	1,765	5,373	4,361	757	32.9
Jeju-do	4	11	16	190	532	636	105	27.1
R2	0.379	0.364	0.342	0.345	0.318	0.308		
P-value	0.019	0.017	0.017	0.021	0.028	0.026		

1 x 10 thousand; 2 per 100,000 persons. Standardized to world standard population; R2 (coefficient of determination) and p-value calculated by the simple linear regression with number of motor vehicles of regions in the corresponding year and incidence of female breast cancer of the regions in 2010.

be calculated with enough lag time and strong association.

Both breast cancer incidence and the mortality rate increased continuously. This increasing trend is parallel with the trend of number of vehicles. But the total gasoline consumption increased until 1997 only and showed a decreasing trend thereafter (Figure 1, Figure 2).

Table 2 presents the breast cancer incidences in 16 provinces with the number of motor vehicles. The linear regression analysis shows that the incidence rates of breast cancer are positively related to the number of vehicles with time lags of 10, 15 and 20 years. The R-squared were 0.379, 0.364, and 0.342 for time lags of 20, 15 and 10 years with a statistical significance (p value=0.019, 0.017 and 0.017, respectively). These results demonstrated about

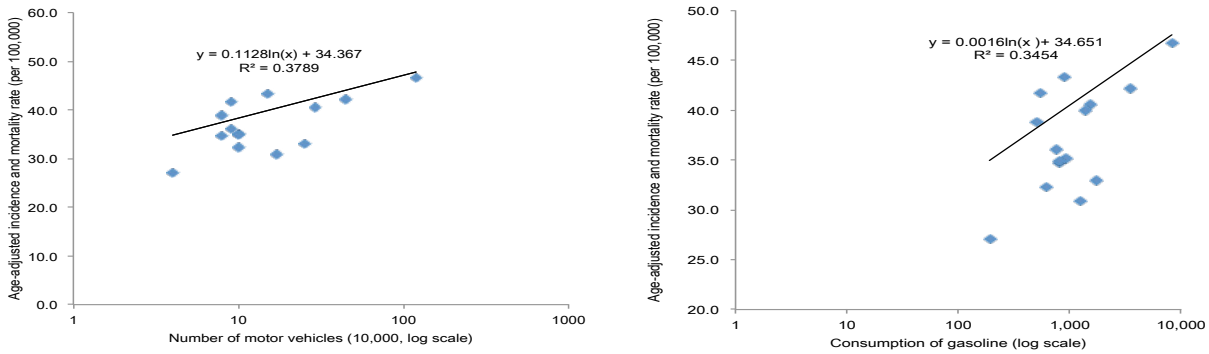

Figure 3. Female Breast Cancer incidence Rate in 2010 by Number of Motor Vehicle and Consumption of Gasoline in 1990 in 16 Regions, Republic of Korea

34-38% of breast cancer variations in the provinces could be explained by the variation of motor vehicle numbers 10~20 years prior.

Table 2 also presents the breast cancer incidences in 16 provinces compared with the consumption of gasoline. During the increase of gasoline consumption the incidents of breast cancer showed an increasing tendency also. The values of R-squared were 0.345, 0.318 and 0.308 for time lags of 10, 15 and 20 years with a statistical significance (p value=0.021, 0.028 and 0.026, respectively). Therefore it might be suggested about 30-34% of the variation of breast cancer incidents in provinces could be explained by the variation of gasoline consumption 10~20 years prior.

Figure 3 presents the log linear relationship between breast cancer incidents in 2010 and the log transformed number of motor vehicles with the log transformed gasoline consumption in 2000. After the application of the log transformed exposure data, the R-squares were 0.367 for the number of motor vehicles and 0.329 for gasoline consumption.

Discussion

In the present study, positive long-term time trend and geographical correlations were observed between breast cancer incidence and the number of motor vehicles, gasoline consumption. Therefore, it could be hypothesized air pollution caused by traffic emission might be one of the risk factors of breast cancer incidence.

Motor vehicular traffic is the main cause of air pollution in urban areas. Many potential carcinogens including particle emissions, volatile organic compounds (Guo et al., 2004), polycyclic aromatic hydrocarbons (PAHs) (Straif et al., 2005) and benzene are included in the vehicle emissions (Nie et al., 2007). Also gasoline includes carcinogens such as benzene or aromatic hydrocarbons (Crouse et al., 2010). Such items could be accumulated in breast cancer tissue and cause mammary carcinogenesis by altering the DNA (Morris and Seifter, 1992). Also diesel is known to produce diesel engine exhaust and has been used as fuel of motor vehicles in Korea for a long time. But for this study only the geographical consumption pattern of gasoline were obtained.

Although traffic-related air pollution contains many kinds of carcinogens, nitrogen dioxide (NO_2) was used as an indicator in some studies. Recently a case-control study showed an increase of 5 ppb NO_2 increased the risk of postmenopausal breast cancer by 25% (Crouse et al., 2010). Another study showed an increase of 5 ppb NO2 increased the risk of prostate cancer by 27~44% (Parent et al., 2013). In some studies, PAH was applied as a proxy of traffic emissions. In one study the lifetime exposure to benzo[a]pyrene, which is one of the most abundant PAH, was calculated using lifetime residential histories. In this study it was shown that an exposure during the menarche period affects the premenopausal breast cancer risk and an exposure during the time point of the first birth affects the postmenopausal breast cancer risk and it was suggested an early life exposure may impact the breast cancer risk (Nie et al., 2007). In a further study, the PAH exposure was calculated at birth using a total of suspended particles as a proxy. The results showed an exposure to PAHs at birth increased the postmenopausal breast cancer risk only (Bonner et al., 2005). Two ecological studies indicated NOx as a major emission of motor vehicles density but vehicle density was applied due to lack of data. In both studies it was proposed there is an association between the time trend, geographical pattern and the breast/lung cancer incidence rate (Chen and Bina, 2012; Chen et al., 2007). Therefore it was expected the number of vehicles and the gasoline consumption which were used as proxy markers for the traffic-related air pollution in this study could reflect the traffic emission as well.

Most of the previous studies applied various lag times although in some studies an exposure at birth was estimated (Bonner et al., 2005). In case-control studies the exposure was estimated using 10to 20 years of lag time before recruitment (Crouse et al., 2010; Nie et al., 2007; Parent et al., 2013) and in ecological studies 20 years of lag time were applied (Chen and Bina, 2012). Therefore, the lag time applied in this study could include an appropriate patent period between exposure and cancer development. In the present analysis, 20 years of lag time showed the strongest association followed by 15 years of lag time and 10 years of lag time, but the degree of decline was minimal (less than R-squared -0.4). The strengths of association in the present estimates were slightly lower than those in a recent Asian study in which the correlation between pollution emissions from stationary sources and the incidence of breast cancer were measured (r=0.77, R-squared=0.59) (Bilyalova et al., 2012). These differences might be due to different sources of pollution

emissions (motor vehicles *vs* stationary sources).

Considering the long term trend, the number of motor vehicles, breast cancer incidence, and mortality showed an increasing trend, otherwise the gasoline consumption increased until 1997 followed by a decreasing trend. The gasoline consumption decreased as well as the diesel consumption (data not shown) since 1997. It might be explained by an increasing use of eco-friendly fuel and increasing concerns about the environmental pollution. However, the positive association between breast cancer incidence and gasoline consumption in the aspect of geographic variations remained after 1997 (in 2000).

The present findings should not be interpreted as an assumption that the numbers of motor vehicles or the amount of gasoline are associated factors. They are proxy markers of the air pollution caused by traffic emissions.

The ecological study method was adapted in this study and therefore there are inherent methodologically limitations. First, the exposure and outcome data were average data and not usable for each individual's value. Therefore, the data might have poor relations existing at an individual level or at a neighborhood level, showing an 'ecological fallacy'(Rothman et al., 2008). However, ecological studies are widely used because they are easy to do and useful for generating hypotheses since they can use existing data sets and rapidly test the hypothesis (Igissinov et al., 2013a; 2013b; 2013c). Second, confounding factors such as reproductive or life-style factors cannot be controlled (Rothman et al., 2008). Although both the long term time trend and the geographical variations were considered and similar increasing trends were found, there is no evidence that this kind of two dimensional analysis could be the way for a confounder control. Although the associations between breast cancer incidence and the number of motor vehicles, gasoline consumption were estimated, data about all components of traffic emission by year and provinces were not available. Therefore the relationship between breast cancer and compounds of traffic emissions could not be calculated. The number of vehicles, the amount of gasoline consumption, and the incidence of breast cancer were based on the registration numbers only. The motor vehicles could be used in another areas from the area where they were registered. However, these could be a non-differential bias and the effects might be estimated as minimal.

In summary, the results of the current study indicate that there are positive relations between the number of vehicles, the gasoline consumption and the incidents of breast cancer in the aspect of long-term trend and geographical variations. Further studies are needed to investigate whether the compounds of traffic emissions are associated with breast cancer risks.

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