International Journal of Medical and Health Research
ISSN: 2454-9142
www.medicalsciencejournal.com
Volume 4; Issue 8; August 2018; Page No. 122-127

Analysis of the correlation of the air pollution indicator and metabolic syndrome in Pingtung area

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Abstract
Background: There are considerable evidences showing that air pollution in our environment is enough to damage health. The relation between air pollution and cardiovascular disease has been established by a large number of epidemiological studies. And metabolic syndrome is closely related to cardiovascular disease.
Purpose: The purpose of this study was to assess the impact of air pollution indicators on metabolic syndrome.
Methods: A cross-sectional design was used. The environmental protection agency monitors two monitoring stations for air pollution in Pingtung: Pingtung City, Chaozhou Station, taking the air pollution indicator of Pingtung area from 2011 to 2015 and referring to the people who had adult health check in a regional hospital in Pingtung City as the study subject. Using the data of the metabolic syndrome related indicators in the physical examination database for analysis to assess the impact of air pollution indicators on metabolic syndrome.
Results: This study is based on the subjects' annual physical examination date (month) and calculate one year forward, and then assess the impact on metabolic syndrome against exposed air pollution indicators. The results show that in the one-year cumulated pollutant impact part: PM10, PM2.5, O_3, SO_2 show significant risks of developing metabolic syndrome. The odds ratio (OR) are respectively OR=1.035 OR=1.035, OR=1.032, OR=1.051, OR=2.062. And CO, NO, NO_2, NO_x, appears to be protection factors, respectively OR=0.029, OR=0.635, OR=0.855, OR=0.975.
Conclusion: The results show that PM2.5, PM10, O_3, SO_2 are risk factors for metabolic syndrome.

Keywords: air pollution indicator, metabolic syndrome, fine particulate matter

Introduction

The relation between air pollution and cardiovascular disease has been established by a large number of epidemiological institutes [1-5]. The relation between short-term exposure to air pollution and human health has been documented in many epidemiological studies around the world [2, 3, 6-10].

Ambient air pollution is associated with an increased risk of cardiovascular disease. Environmental pollution causes adverse effects on the heart through pulmonary inflammation, systemic inflammation, oxidative stress, endothelial dysfunction, and changes in thrombosis [11].

A study in São Paulo found that air pollution has a stronger impact on congestive heart failure for male, and on cardiovascular and ischemic heart disease for women. This raises the need for additional research on "Air Pollution's Impact on Health by Gender" [12]. Kan *et al*. shows the impact of air pollution, SO_2 among all has most significant impact on female. Older women have an increased chance of stroke death under exposure to PM10 [13, 14]. Studies in urban areas and medium-sized cities show that, acute myocardial infarction (AMI) hospitalization is associated with exposure to air pollutants. Among them, particulate matter (PM10), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO) are most related to AMI [12-23].

In the São José dos Campos study, exposure to CO is also a significant factor in AMI hospitalization [15]. Chen *et al*. found that the risk factor for death of Coronary disease (CD) is caused by PM10 and PM2.5 exposure, significantly more prominent among female than male, and it is so for both analyses of single and multiple pollutants.

Over the past two decades, there has been concern about global environmental air pollution and its impact on human health. Most health problems are related to long-term exposure to environmental pollution. Diseases related to the environment are obtained in childhood, manifested in adulthood, and are not easily diagnosed [24]. Air pollution is heterogeneous and complicated, a mixture of dust, smoke, gases, CO, NO_2, SO_2, and O_3 [25-27]. Literature indicates that the amount of particulate matter PM is associated with the increase in arterial blood pressure. For every 10 g/m^3 increase in PM, the blood pressure rises by 1-4 mmHg [28]. Long-term exposure to high PM 2.5 μm is associated with higher circulating endothelin concentrations (ET-1) and the increase of pulmonary arterial pressure [29]. Wu *et al*. found that temperature and traffic-related air pollutants PM $\leq$ 2.5 μm (organic carbon, elemental carbon and nitrogen dioxide) have a significant interaction with blood pressure.

In the follow-up study report of Danish adults, as the average residential NO_2 level rises slowly over the past 35 years, hospitalization rates for asthma, chronic obstructive pulmonary disease, and stroke are also increasing [30-32]. Studies have shown that the risk of hospitalization for respiratory and cardiovascular diseases increases with regional NO_2 criteria [33].

Located in the southernmost tip of Taiwan, there is no heavy industry in Pingtung, but the air quality is one of the worst. In addition, the ozone pollution in Chaozhou has been the most severe for three years, and this year's Pingbei has more days of bad air quality than Kaohsiung. Why is the air quality in Pingtung so low? Environmental health groups explained that although there is no heavy industry in Pingtung, due to wind direction and terrain restrictions, pollutants from the nearby heavy industry in Kaohsiung City were blown to Pingtung, and further blocked by Dawu Mountain and landed in Chaozhou. In 2017, the number of days for over-standard PM2.5 in Pingbei was also higher than in nearby Kaohsiung City, especially in December, when the days of low air quality reached 80.6%, which was higher than 69.4% in Kaohsiung City. And according to the statistics from the Environmental Protection Agency (EPA), the annual number of over-standard days in Chaozhou Station ranked third in the country.

The purpose of this study is to use the metabolic syndrome of physical examination data as a risk indicator for cardiovascular disease to conduct an analysis related to air pollution indicators.

Materials and methods

Study design

This is a cross-sectional study, using people participated in the adult health examination of a regional hospital in Pingtung City from 2011 to 2015 as subjects. Using personal data of the health examination database, physical examination and blood test data for data processing. Using the air monitoring station in Pingtung area to collect air pollution indicators for air quality indicators monitoring from 2011 to 2015, such as aerosols (PM10) (fine particles with a particle size of 10 microns or less), (PM2.5) (fine particles), CO, nitric oxide (NO), NO_2, nitrogen oxides (NOx), O_3 and SO_2, analyzing the impact of these values on metabolic syndrome (as a risk indicator for cardiovascular disease).

Participants

Using those who participated in adult health check-ups (or integrated screening) from 2011 to 2015 as subjects; deducting those who did not complete their physical examinations or biochemical blood tests. Mainly analyzing the physical examination data and the dependent variables are metabolic syndrome and component factors.

Data collection

1. Body mass index (BMI) was defined as weight (kg) divided by height squared (m^2).
2. Waist circumference (WC): WC was measured to the nearest 0.1cm on bare skin midway between the lower rib margin and the iliac crest at the end of gentle expiration.
3. Blood pressure (BP): Trained nurses measured the systolic blood pressure (SBP) and diastolic blood pressure (DBP) in the left arm of seated participants twice according to a standardized protocol. A third BP measurement was made if the first two BP readings differed by more than 10 mm Hg. The average of the two closest readings was calculated to determine the reported BP for each participant.
4. Biochemical examinations: Participants were required to fast for a minimum of 10 hours prior to the biochemical blood test which measured triglycerides, high-density lipoprotein cholesterol (HDL-C), and plasma glucose levels.

Definition of variables

Metabolic Syndrome Was Defined According to the Criteria Set by the Health Promotion Administration, Ministry of Health and Welfare, in 2007: Accordingly, three of the following five criteria were grounds for definition: (1) elevated blood pressure: blood pressure of at least 130/85 mmHg or use of antihypertensive medications, (2) hypertriglyceridemia: serum triglycerides (TG) of at least 150 mg/dL, (3) reduced high-density lipoprotein cholesterol (HDL-C): HDL-C < 40 mg/dL in men and < 50 mg/dL in women, (4) hyperglycemia: raised fasting plasma glucose (FPG) of 100 mg/dL or more or use of drug treatment of elevated glucose, and (5) central obesity: waist circumference ≥ 90 cm in men and ≥ 80 cm in women.

Ethical considerations

The data collection and analysis in this study began after the study proposal was reviewed by the Institutional Review Board (IRB).

Statistical analyses

The mean and standard deviation (SD) were used to describe continuous variables. Inferential statistics applied the Chi-Square test ($\chi 2$) and multiple logistic regression. Logistic regression models were applied to analyze the association of metabolic syndrome with higher air pollution indicators after adjusting for other relevant factors (age, sex, BMI, circumference, heart disease, diabetes). The strength of association was indicated by odds ratio (OR) and 95% confidence interval (CI). P values < 0.05 were considered statistically significant, and all statistical tests were two-tailed. All statistical analysis was conducted using the SPSS 20.0 software package for Windows (SPSS Taiwan Corp).

Results

Table 1 and 2 show the annual average concentration of air pollution indicators in Pingtung station and Chaozhou station from year 2011 to 2015. Due to topographical and climatic factors, air pollution is the most severe from October to the next February in Pingtung area, other months are normal; therefore, the annual average air pollution indicators is still within the normal range.

Difference analysis of metabolic syndrome and component factors in different years from 2011 to 2015. The results show that metabolic syndrome and component factors reach statistically significant differences each year; although there is higher ratio of normal indicators in each year, the proportion of abnormal blood pressure was found to be significantly higher than normal in each year. Among them, the abnormality of metabolic syndrome was mostly around 35% each year, which was obviously higher (Table 3).

This study investigated the effects of air pollution indicators on the development of metabolic syndrome. Assume that the subjects have an impact on metabolic syndrome indicators after receiving air pollutants for one year, leading to metabolic syndrome. Therefore, after respectively calculated one year ahead from subjects’ physical examination date (month) each year, evaluated the impact on developing metabolic syndrome against exposed air pollution indicators, and adjusted related impact factors such as gender, age, BMI, waist circumference, heart disease, and diabetes, the results (Table 4) indicate that in the impact of accumulating pollutant for a year part: PM10, PM2.5, O_3, and SO_2 showed significant risk of metabolic syndrome, and the odds ratio (OR) was respectively OR=1.035 OR=1.035, OR=1.032, OR=1.051, OR=2.062. And CO, NO, NO_2, NO_x appeared to be protection factors, with respectively OR=0.029, OR=0.635, OR=0.855, OR=0.975.

Table 1: Annual average concentration of air pollution indicators from year 2011 to 2015 in Pingtung Station

Year/Indicator	2011	2012	2013	2014	2015
CO	0.54±0.11	0.52±0.09	0.51±0.11	0.49±0.11	0.46±0.12
NO	2.99±0.76	2.66±0.67	2.12±0.43	2.17±0.60	1.90±0.34
NO2	14.68±4.98	14.25±3.03	14.59±3.70	14.91±4.26	13.59±4.12
NOx	17.66±4.96	16.91±3.29	16.70±3.81	17.07±4.58	15.49±4.23
O3	32.93±8.35	30.92±8.06	32.06±7.47	33.32±8.81	31.16±6.52
PM10	75.84±25.23	70.22±17.45	66.21±23.45	62.14±23.64	56.95±22.34
PM2.5	40.69±15.41	37.59±12.51	42.95±12.90	27.89±14.60	26.40±13.62
SO2	3.74±0.81	3.24±0.51	3.40±0.64	3.28±0.66	2.91±0.51

Table 2: Annual average concentration of air pollution indicators from year 2011 to 2015 in Chaozhou Station

Year/Indicator	2011	2012	2013	2014	2015
CO	0.37±0.14	0.35±0.13	0.34±0.14	0.33±0.12	0.33±0.13
NO	2.60±0.92	1.92±0.69	1.57±0.33	1.55±0.43	1.57±0.38
NO2	10.67±4.87	8.85±4.16	9.15±4.07	9.70±4.03	9.50±4.42
NOx	13.26±5.73	10.77±4.77	10.72±4.33	11.24±4.34	11.06±4.70
O3	30.96±7.43	29.87±8.57	30.91±7.82	34.26±8.98	32.21±7.03
PM10	68.28±27.02	63.11±21.68	69.77±28.57	63.17±24.89	57.55±26.29
PM2.5	44.63±17.27	38.85±13.86	41.67±16.31	29.84±13.17	27.06±13.00
SO2	3.36±0.81	2.71±0.59	2.88±0.64	3.10±0.58	2.69±0.49

Table 3: Difference analysis of metabolic syndrome and component factors in different years from 2011 to 2015

Year/Metabolic syndrome and component factors	2011	2012	2013	2014	2015	P Value
Metabolic Syndrome						0.030
Yes	426(35.7%)	1054(32.8%)	1593(35.8%)	1412(36.2%)	1149(35.4%)	
No	767(64.3%)	2156(67.2%)	2852(64.2%)	2484(63.8%)	2094(64.6%)	
Waist circumference						0.002
Abnormal	534(44.8%)	1312(40.9%)	1991(44.8%)	1759(45.1%)	1451(44.7%)	
Normal	659(55.2%)	1898(59.1%)	2454(55.2%)	2137(54.9%)	1792(55.3%)	
BMI						0.001
Abnormal	284(23.8%)	736(22.9%)	1168(26.3%)	1031(26.5%)	896(27.6%)	
Normal	909(76.2%)	2474(77.1%)	3277(73.7%)	2865(73.5%)	2347(72.4%)	
Blood Pressure						0.020
Abnormal	632(53.0%)	1654(51.5%)	2441(54.9%)	2140(54.9%)	1725(53.2%)	
Normal	561(47.0%)	1556(48.5%)	2004(45.1%)	1756(45.1%)	1518(46.8%)	
Blood Sugar						0.001
Abnormal	434(36.4%)	1413(44.0%)	1870(42.1%)	1685(43.2%)	1318(40.6%)	
Normal	759(63.6%)	1797(56.0%)	2575(57.9%)	2211(56.8%)	1925(59.4%)	
Triglyceride						0.001
Abnormal	293(24.6%)	781(24.3%)	1306(29.4%)	1078(27.7%)	920(28.4%)	
Normal	900(75.4%)	2429(75.7%)	3139(70.6%)	2818(72.3%)	2323(71.6%)	
HDL						0.001
Abnormal	555(46.5%)	985(30.7%)	1272(28.6%)	1252(32.1%)	1084(33.4%)	
Normal	638(53.5%)	2225(69.3%)	3173(71.4%)	2644(67.9%)	2159(66.6%)	

Table 4: Analysis of the impact of the overall annual air pollution indicators on metabolic syndrome (one year cumulative) from year 2011 to 2015

Overall Year	OR	95CI%		p-value
PM10	1.035	1.022	1.048	<0.001
PM2.5	1.032	1.023	1.041	<0.001
CO	0.029	0.001	0.750	0.033
NO	0.635	0.56	0.721	<0.001
NO_2	0.855	0.774	0.945	0.002
NOx	0.975	0.739	0.856	<0.001

O_3	1.051	1.015	1.087	0.005
SO_2	2.062	1.642	2.588	<0.001

Adjusted: gender, age, BMI, waist circumference, heart disease, diabetes

Discussions

The issue of air pollution is gaining more attention in Taiwan gradually. In addition to the effects on the respiratory tract, there is a considerable proportion of cardiovascular problems that can lead to cardiovascular disease. Located at the southernmost tip of Taiwan, Pingtung is the most severe area of air pollution, therefore, it is a topic worth attention.

This study assumes that air pollution exposure for more than a year is more likely to cause cardiovascular disease (metabolic syndrome as target). We calculated one year ahead from subjects' physical examination date (month) each year, evaluated the impact on developing metabolic syndrome against exposed air pollution indicators, and after adjusting the related impact factors, according to the results of the three important pollution indicators PM2.5, PM10 and O_3, the impact of accumulating pollutant for a year part: PM2.5 fine aerosol, PM10 and O_3 are the three important pollution indicators of metabolic syndrome risk factors.

Some documents indicate that the amount of particulate matter PM is related to the increase in arterial blood pressure. For every 10 g/m^3 increase in PM, the blood pressure rises by 1-4 mmHg [28]. Long-term exposure to high PM 2.5 μm and higher circulating endothelin concentrations (ET-1) are also associated with increased pulmonary arterial pressure [29]. Wu *et al* found out that temperature and traffic-related air pollutants PM ≤ 2.5 μm (organic carbon, elemental carbon and nitrogen dioxide) have significant interaction with blood pressure. They concluded that low-temperature air pollution affects blood pressure more than high temperature [34]. There was a study of the impact of air pollution on mortality in England in 2016; 367,658 subjects were recruited for the study, and selected the measured concentration of sulfur dioxide and black carbon in the three years of 1971, 1981, and 1991, and the PM_{10} pollutant in 2001, and investigate the mortality rate of the subjects between 2002 and 2009. The result of short-term study shows that if there are 10 μg/m^3 of PM_{10} increased per year, there would be 22% increase in respiratory mortality and 12% cardiovascular mortality between 2002 and 2009 [35]. Li and Chen [36], Ghosh *et al* [37], Wang *et al*. [38], Gan and Davies [39], Scarborough *et al*. [40]; de-Kluizenaar *et al*. [41] confirmed the correlation between air pollutants, coarse particle concentration (PM 2.5-10 μm) and the hospitalization frequency and mortality due to cardiovascular disease. They have stated that the increase in PM (particulate matter), sulfur dioxide and nitrogen dioxide increases environmental pollution coronary heart disease (CHD). Mustafic *et al*. [42] also finds that short-term exposure to air pollutants, including carbon monoxide, nitrogen dioxide, sulfur dioxide and PM 2.5-10 μm, are all associated with acute coronary syndrome and myocardial infarction. Study shows that in the first 1 to 5 days, with 10μg/m3 of PM2.5 increased, the daily cardiovascular disease (CVD) mortality increased by 0.4–1.0%. The increase in hospitalization due to CVD is also associated with daily changes in PM. The American Heart Association had stated that there is high evidence proving there are short-term effects of PM2.5 on the morbidity and mortality in ischemic heart disease; moderate (but more and more) evidence has implied the effects on heart failure and ischemic stroke. There is also a small number or mixed evidence shows the effects on peripheral blood vessels and arrhythmias [43].

This study is similar to some of the study results. However, with the study limitations 1. The air pollution monitoring stations in Pingtung area are only in Pingtung City and Chaozhou, using these monitoring station data to estimate the physical examination data from the hospital and the association of metabolic syndrome may be biased. And since the estimation of the effects of pollutants exposure on individuals with metabolic syndrome is calculated a year ahead, it is difficult to correctly assess whether one year of exposure is sufficient to cause metabolic syndrome. Therefore, some of the pollutants become protective factors. But because of the large number of samples in this study, it is preliminary precursor analysis, so it can still be referred to related research and future studies. 2. This study can only present the discussion of the correlation between demographic characteristics, science, biochemical blood tests and metabolic syndrome. Since it uses physical examination data for analysis, it fails to fully collect potential impact factors that affect metabolic syndrome, the inference must also be conservative.

Conclusions

In general, the study results show the three pollutants PM2.5, PM10, O_3 as risk factors for metabolic syndrome.

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