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Research Article

Fine Particulate Air Pollution and Ischaemic Heart Disease in Chinese Cities: A Narrative Review

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Abstract

The purpose of this study is to investigate the association between fine particulate matter and ischaemic heart disease. A literature search was conducted using six electronic databases (Embase, Scopus, PubMed, Google Scholar, Cochrane Library and Web of Science) and the University of Queensland's online library. A list of important sources was compiled and reviewed, and the ten best resources selected, based on their focus on Chinese cities and the administrative city of Hong Kong. The other criterion used to select the articles was that they must address and contain at least one outcome of the relationship between particulate matter and ischaemic heart disease. The result of the review indicates that both types of particulate matter (PM10 and PM2.5) have a strong association with ischaemic heart disease. Low and high concentrations of particulate matter have unhealthy effects on ischaemic heart disease mortality, morbidity, emergency visits and hospital admissions. Elderly subjects appear more susceptible to the harmful effects of particulate matter. In this narrative review, particulate air pollution manifests higher ischaemic heart disease risk in male, this can be attributed to high exposure level of air pollution and tobacco smoking in men than women in China. Staying at home or using a face mask during low and elevated levels of particulate matter concentration will help improve the cardiovascular health of vulnerable people. The health consequences of particulate matter cannot be ignored in the prevention of ischaemic heart disease. Policy makers in China and Hong Kong should target the implementation of appropriate measures that will reduce particulate matter exposure.

Keywords: Concentration & effects; Coronary heart disease; Ischaemic heart disease; Particulate matter

Abbreviations: PM: Particulate Matter; IHD: Ischaemic Heart Disease; CHD: Coronary Heart Disease

Introduction

Ischemic Heart Disease (IHD), also known as coronary heart disease, is distinguished by myocardial ischaemia due to the contraction of the coronary vessels which supply blood to the heart [1]. IHD is one of the main causes of death globally among women and men [2]. According to the Global Burden of Disease study in 2010, the occurrence of IHD deaths increased from 450.3 million in 1990 to 948.7 million in 2010 [3]. The prevalence of IHD has been increasing over recent decades in Chinese cities. The standardised mortality rate of IHD in the Chinese population increased from 62.52 per 100,000 people in 1990 to 77.89 per 100,000 people in 2010; hence, over 900,000 deaths can be attributed to IHD in 2010 [4].

It is increasingly acknowledged that fine, particulate air pollution exerts an extensive range of harmful effects on human health. Several studies on air pollution in Chinese cities support the association between fine particulate matter and IHD mortality, morbidity and hospital admissions [3]. These effects can be attributed to short-term, long-term and acute exposure to increased concentrations of particulate matter [3-5]. Those whose age falls in the range of 40 to 65years, the elderly, those with co-morbidities and males who work outside are more prone to the harmful effects of particulate air pollution [1,6,7]. The purpose of this study is to investigate the relationship between fine particulate matter and ischaemic heart disease.

Methods and Materials

Search Strategy

A literature search was carried out using six electronic databases, Embase, Scoopus, PubMed, Google Scholar, Cochrane Library and Web of Science, as well as the University of Queensland's online library. The search was performed using key words without time limits: "Fine particulate air pollution, air pollution, health, particulate matter, ischaemic heart disease, coronary heart disease, cardiovascular disease, mortality, morbidity, short term and long-term effects exposure". The last date of the search was September 30, 2017. The references of all selected articles were analysed for more relevant articles.

Selection and Review Process

Once the list of important studies was compiled and reviewed, the ten best resources were selected, based on the following study criteria: 1) focused on China and its administrative city of Hong Kong; 2) addressed fine particulate air pollution and ischaemic heart disease; 3) addressed fine particulate air pollution and coronary heart disease; 4) focused on fine particulate air pollution and cardiovascular heart disease; and 5) included at least one outcome of the relationship between fine particulate matter and ischaemic or coronary heart disease. Data collected from the articles included information on the type of studies, the effects of short-term exposure to Particulate Matter (PM) on IHD, the effects of long-term exposure to PM on IHD, IHD morbidity and mortality due to exposure to PM, IHD hospital admissions and emergency visits as a result of exposure to PM, and the age group and gender more susceptible to IHD due to exposure to PM.

Components of Particulate Matter

PM is made up of particles that are categorised on the basis of their size. PM is classified into coarse (diameter < 10µm; PM_{10}) and fine (diameter < 2.5µm; $PM_{2.5}$). PM_{10} sources consist of soil/road dust (e.g., from unpaved roads and dirt), vehicle exhaust, residual oil combustion (e.g., fuel emissions from marine vessels), regional combustion, fresh sea salt, aged sea salt, secondary sulphate and secondary nitrate [8]. $PM_{2.5}$ is obtained mainly from combustion and contains a mixture of toxic metals and organic carbon, including polycyclic aromatic hydrocarbon. $PM_{2.5}$ is more toxic than PM_{10}, the latter consisting of a substantial proportion of the former. $PM_{2.5}$ has a smaller, aerodynamic diameter that can penetrate deep down into the parenchyma of the lungs and the respiratory tract [9]. Here, it may activate ischaemic heart disease via diverse channels, such as increasing blood viscosity, increasing inflammation, increasing vasoconstriction and causing abnormal regulation of the cardiac automatic system [3].

The Association of Particulate Matter with Ischaemic Heart Disease Mortality and Morbidity

Xie, et al. [10] conducted a time series study to examine the short-term dose-response association between $PM_{2.5}$ and IHD morbidity and mortality in Beijing. The automatic Met One Bam-1020 beta (β) attenuation mass monitor was used to monitor the hourly concentration of $PM_{2.5}$. Cases of IHD were established by using records of hospital admissions and deaths. In 1096 days, a total of 53,247 deaths and 34,0819 admissions were collected. Lastly, 369,469 cases of IHD morbidity were examined. These included 1,1851 cases of chronic IHD, 199,209 cases of acute IHD, and several types of IHD. Mortality results included 53,247 IHD deaths, of which 13,869 and 39,380 deaths occurred in and out of hospitals, respectively. Of the 369,469 IHD cases that occurred during the study period, 59.9 percent were male cases and 44.6 percent were under 65 years of age. Among 53,247 deaths, 74 percent occurred out of hospital (Table 1). On average, 337 IHD cases and 49 IHD deaths occurred per day. The study discovered clear dose–response relationships between $PM_{2.5}$ concentrations and IHD mortality and morbidity. The relationships were non-linear, with a shallower dose-response function at higher concentrations and a steeper dose-response function at lower concentrations. As demonstrated in Table 2, after adjusting for seasonality, weather conditions, time influence and days of the week, a 10µg/m^3 rise in $PM_{2.5}$ was associated with a 0.27 percent rise in IHD morbidity and a 0.25 percent increase in mortality. Significant lag associations of $PM_{2.5}$ with IHD morbidity were noticed at lag 1, 2 and 3 days, however, no significant lag relationship with IHD mortality was observed. An increase in concentration of $PM_{2.5}$ on days 3 and 5 was highly correlated with IHD mortality and morbidity.

Xie, et al. [10] also found out that, among people ≥ 65years, the 3-day and 5-day averages of $PM_{2.5}$ significantly correlated with IHD mortality and morbidity. Whereas, for those who fell in the age range of < 65years, a significant association was discovered with IHD morbidity. Older people had a significantly stronger association of $PM_{2.5}$ with IHD mortality and morbidity. The association of $PM_{2.5}$ and IHD morbidity and mortality were significant for men and women. However, there was a stronger association of morbidity in women than in men, while no gender distinction was noticed for IHD mortality. Xu, et al. [3] used spatiotemporal analysis to examine the short-term impacts of PM_{10} concentration on IHD mortality. During 2008 and 2009, daily data on air pollution, weather conditions and IHD mortality were gathered in Beijing, China. Kriging was employed to interpolate the daily PM_{10} concentrations of 287 township level districts, based on 27 monitoring sites encompassing the whole city. A generalised addictive model was used to examine the average impact of PM_{10} concentration and to quantify the effect of spatially resolved PM_{10} on IHD mortality.

Xu, et al. [3] found that, in spatiotemporal analysis, PM_{10} concentration was significantly associated with IHD mortality, with the strongest impacts discovered for the two-day average. A 10μg/m³ rise in PM_{10} correlated with an increase in daily IHD mortality. The impact estimates using spatially resolved PM_{10} were greater than when using average PM_{10}. Table 3 demonstrates that PM_{10} had a stronger impact on IHD mortality in summer than in other seasons. Adult males and older people manifest more extreme reactions to PM_{10} exposure.

	Men			Women		
	<45 years	45-65 years	≥ 65years	<45 years	45-65 years	≥65years
IHD cases	13,971	105,553	101.902	1,653	43,723	102,632
Acute	7,526	56,738	55,354	765	22,194	56,632
Chronic	3,423	25,911	33,210	547	13,435	35,325
Others	3,022	22,904	13,338	341	8,094	10,710
IHD deaths	959	6,335	21,317	190	2,035	22,411
In-hospital	83	961	6,360	29	423	6,011
Out-of-hospital	876	5,374	14,957	161	1,612	16,400

Table 1: Number of cases and deaths from Ischaemic Heart Disease (IHD) in Beijing from 2010 to 2012, by sex and age [10].

	Percentage change (95% CI)	p value
Morbidity		
Lag 0 days	0.27 (0.21 to 0.33)	$<2.00 \times 10^{-16}$
Lag 1 day	0.16 (0.11 to 0.21)	5.56×10^{-16}
Lag 2 days	0.15 (0.10 to 0.19)	7.76×10^{-11}
Lag 3 days	0.07 (0.03 to 0.12)	9.18×10^{-4}
Lag 4 days	0.02 (-0.02 to 0.07)	3.00×10^{-1}
Lag 0-2 days	0.35 (0.28 to 0.43)	$<2.00 \times 10^{-16}$
Lag 0-4 days	0.25 (0.16 to 0.34)	2.43×10^{-8}
Mortality		
Lag 0 days	0.25 (0.10 to 0.40)	1.15×10^{-3}
Lag 1 day	0.00 (-0.13 to 0.40)	9.67×10^{-1}
Lag 2 days	-0.11 (-0.23 to 0.00)	5.72×10^{-2}
Lag 3 days	-0.17 (-0.28 to -0.05)	3.95×10^{-3}
Lag 4 days	-0.11 (-0.22 to 0.01)	6.25×10^{-2}
Lag 0-2 days	0.34 (0.14 to 0.53)	7.12×10^{-4}
Lag 0-4 days	0.26 (0.03 to 0.49)	2.94×10^{-2}

Table 2: Percentage change and 95% Confidence Interval (CI) in morbidity and mortality from ischaemic heart disease associated with a 10μg/m³ increase in fine particulate matter ($PM_{2.5}$) concentration for different lag days [3].

Lag	Season	Percent change (95% CI)
Lag 0	Spring	0.17(-0.07, 0.40)
	Summer	0.60(0.13, 1.06) *
	Autumn	0.35(0.06, 0.64) *
	Winter	0.23(-0.06, 051)
Lag 1	Spring	0.19(-0.05, 0.43)
	Summer	0.68(0.22, 1.14) *b
	Autumn	0.27(-0.01, 0.56)
	Winter	0.12(-0.16, 0.41)
Lag 2	Spring	0.03(-0.21, 0.27
	Summer	0.43(-0.03, 0.09) b
	Autumn	-0.08(-0.37, 021)
	Winter	-0.16(-0.44, 0.12)
Lag 3	Spring	0.24(-0.02, 0.51)
	Summer	0.83(0.31, 1.5) *a
	Autumn	0.41(0.08, 0.73) *
	Winter	0.27(-0.06, 0.60)
Lag 4	Spring	0.22(-0.06, 0.60)
	Summer	0.88(0.31, 1.45) *ab
	Autumn	0.29(-0.06, 0.65)
	Winter	0.14(-0.22, 0.51)
Note: *P<0.05 *the difference of effect estimate between summer and spring was statistically significant (p<0.05) bthe difference of effect estimate between summer and winter was statistically significant Cl: Confidence Interval		

Table 3: Percentage increase in IHD mortality associated with 10µg/m³ increase in PM_{10} concentrations by four seasons, using the single-pollutant model in GAMN [3].

Short Term Exposure to Particulate Matter and Ischaemic Heart Disease Mortality

Li, et al. [2] carried out a retrospective, ecological analysis, using time series, in six urban areas in Tianjin, China. The aim of the study was to determine the impact of short-term exposure to PM_{10} on ischaemic heart disease in terms of years of life lost and mortality. The data for the study included 28,365 ischaemic heart disease deaths registered between 2002 and 2006. Table 4 shows the interquartile range increase of PM_{10} associated with increase in years of life lost from ischaemic heart disease of 13.8years. The impacts associated with the interquartile range increase in PM_{10} were larger in women than in men. During 2002 to 2006, there were 27,485 years and 1,252 deaths caused by PM_{10} pollution, which were over the anticipated rates and occurred when daily levels did surpass the World Health Organization air quality recommendations.

Li, et al. [11] obtained data from eight Chinese cities between 1996 and 2008, in order to determine the association between short-term exposure to ambient air and Coronary Heart Disease (CHD), also known IHD. They gathered the specific impact estimates of air pollution using general addictive models. A random-effect model in metal analysis was used to gather the exposure response relationships. Table 5 indicates that an increase of 10µg/m³ in two-day moving average concentrations of PM_{10}

is significantly associated with an increase of 0.36% in daily CHD (IHD) mortality in eight Chinese cities. The exposure-response relationship between PM_{10} and daily CHD (IHD) mortality is linear. A significant increase in CHD (IHD) mortality risk was noticed, even when air pollution concentrations were below 150µg/m^3 for PM_{10}. Li, et al. [11] also discovered that PM_{10} had similar effects both in cool and warm seasons.

Pollutant and model [ab]	Years of life lost (years)	Increase in deaths (%)
PM_{10}		
Single pollutant model	13.8 (4.9 to 22.8) *	4.2 (1.5 to 6.9) *
+ SO_2	14.5 (4.8 to 24.1) **	4.6 (1.7 to 7.5) **
+NO_2	2.2 (-9.1 to 13.6)	0.9 (-2.4 to 4.3)
+SO_2+NO_2	3.5 (-8 to 14.9)	1.3 (-2.1 to 4.7)
SO_2		
Single pollutant model	4.8(-8.8 to 18.4)	1.1 (-2.8 to 5.1)
+PM_{10}	-2.4 (-17.9 to 13)	-1.1 (-5.4 to 3.4)
+NO_2	-7.7 (-24.8 to 9.4)	-2.9 (-7.6 to 2)
+PM_{10}+NO_2	-8.4 (-25.8 to 9)	-3.2 (-7.9 to 1.7)
NO_2		
Single pollutant model	22.7 (11.7 to 33.8) *	6.6 (3.3 to 10) **
+PM_{10}	20.1 (6.2 to 34.1) **	5.5 (1.3 to 9.8) **
+SO_2	29.3 (16.3 to 42.3) **	8.8 (4.8 to 12.9) **
+PM_{10}+SO_2	26.4 (11.2 to 41.6) **	7.5 (2.8 to 12.3) **

Data are mean (95% CI) and are controlled for seasonality, day of the week, temperature and relative humidity; NO_2: nitrogen dioxide; PM_{10}: particulate matter with an aerodynamic diameter of less than 10µm; SO_2: sulphur dioxide.
*P<0.05
**P<0.01.
*PM_{10} and NO_2, lag0-2; SO2, lag 0 to 1.
[b]IQRs were 69.6µg/m^3 for PM_{10} 72.3 µg/m^3 for SO_2 and 24.7µg/m^3 for NO_2

Table 4: The association between Interquartile Range (IQR) increases in air pollutants and years of life lost and increase in ischaemic heart disease deaths, using single, two and three pollutant models during 2002 to 2006 [2].

	Mean	95% CIs
PM_{10}	0.36	0.12, 0.64
+SO_2	0.26	0.05, 0.48
+NO	0.21	0.03, 0.39
SO_2	0.86	0.30, 1.41
+PM	0.41	-0.15, 0.96
+NO_2	0.25	-0.07, 0.56
NO_2	1.3	0.45, 2.14
+PM_{10}	0.65	0.16, 1.14

+SO_2	1.12	0.16, 2.01
Abbreviations: CHD, coronary heart disease; PM_{10}, particulate matter ≤ 10μm in aerodynamic diameter; SO_2, sulphur dioxide; NO_2, nitrogen dioxide, CIs, confidence intervals		

Table 5: Percentage change (means and 95% Cls) in daily mortality associated with 10μg/m^3 increase in 2-day moving average concentration of air pollutants in single- and two-pollutant models [11].

Long-Term Exposure to Particulate Matter and Ischaemic Heart Disease

Zhang, et al. [5] conducted a retrospective, cohort study from 1998 to 2009 to ascertain the association between prolonged exposure to PM_{10} and IHD. The study took place in four Chinese cities (Shenyang, Taiyuan, Tianjin and Rizhao) containing 39,054 subjects. Information on the levels of PM_{10} was collected from the local environmental monitoring centres. The estimated exposure for the study population was the mean concentration of PM_{10} over the surviving years during the retrospective cohort study. For each 10μg/m^3 increase in PM_{10}, the Relative Risk (RR) was 1.37 (95% Cl, 1.28-1.47). Table 6 shows the results from stratified analyses, which reveal that the impacts of PM_{10} on IHD mortality are more evident in males, people of higher socio-economic status and smokers. Long term exposure to PM_{10} increases mortality from IHD.

Characteristic	Ischaemic heart disease			
	NO	RR (95% CI) [a]	RR (95% Cl) [b]	p [c]
Age				0.22
<60	43	1.43(1.24-1.65)	1.5 (1.28-1.77)	
≥60	119	1.33 (1.23-1.44)	1.3 (1.21-1.41)	
Sex				0.74
Male	119	1.45 (1.33-1.57)	1.39 (1.29-1.50)	
Female	43	1.34 (1.18-1.53)	1.33 (1.17-1.51)	
Educational level				0.00
Low	119	1.34 (1.25-1.44)	1.28 (1.19-1.38)	
High	43	1.99 (1.68-2.35)	1.74 (1.51-2.00)	
Personal income				0.00
Low	97	1.21 (1.13-1.30)	1.21 (1.13-1.30)	
High	65	2.30 (2.01-2.62)	1.88(1.66-2.13)	
Smoking status				0.00
Never	107	1.30 (1.21-1.40)	1.25 (1.17-1.35)	
Former and current	55	1.83 (1.59-2.11)	1.71 (1.51-1.94)	
Occupational exposure				0.05
No	144	1.38 (1.28 -1.48)	1.35 (1.26-1.44)	
Yes	18	2.61 (1.96-3.48)	2.08 (1.46-2.98)	

Table 6: Estimated RRs for ischaemic heart disease mortality associated with an increase of 10μg/m^3 in PM_{10}, according to selected characteristics [5].

The Association of Particulate Matter with Emergency Visits and Hospital Admissions

Pun, et al. [8] discovered the sources contributing to PM_{10} mass and evaluated the severe impacts of the PM_{10} sources on daily emergency hospitalisations for IHD in Hong Kong. The analyses were conducted between 2001 and 2007, using positive matrix factorisation to apportion PM_{10} mass, and used general addictive models to estimate the relationships between IQR increases in PM_{10} exposure and IHD hospitalisation, for various lag periods.

Pun, et al. [8] report that PM_{10} from nitrate-rich secondary PM, vehicle exhaust, and sea salt were strongly related with increased IHD hospitalisation risk in Hong Kong. Table 7 further demonstrates the findings of this study.

Variable	No. of days	Daily mean ±SD	Percent of PM_{10}	IQR
Emergency hospital admissons				
IHD	2,556	30± 7		9
Meteorological conditions				
Temperature (˚C)	2,556	23.6± 4.9		8.1
Relative humidity (%)	2,556	78.3 ± 9.9		11.4
PM_{10} concentration (μg/m^3)				
Total PM_{10}	1,805	8.4± 3.7	15.1	4.9
Vehicle exhaust	1,805	7.5± 9.0	13.4	6.9
Soil/road dust	1,805	7.5± 9.3	13.5	11.7
Regional combustion	1,805	2.4±2.5	4.3	2.2
Residual oil	1,805	2.1±2.7	3.7	2
Fresh sea salt	1,805	7.2±4.4	12.8	5.9
Aged sea salt	1,805	8.2±8.8	14.9	8.6
Secondary sulphate	1,805	13.2±12.7		

Table 7: Descriptive statistics for PM_{10} sources, meteorological factors, and number of emergency hospital admissions in Hong Kong, 2001-2007 [8].

Xu, et al. [1] investigated the relationship between the exposure to PM_{10} and patient hospitalization due to IHD, during 2013 and 2014 in Shanghai, China. Daily IHD hospitalisation data were obtained from the Shanghai Health Insurance Bureau. The concentrations of air pollution, as well as meteorological data, were collected from the database of Shanghai Environmental Monitoring Centres and were analysed via standard epidemiological methodology. A generalised linear model was used to calculate the immediate and delayed impacts of PM on IHD hospitalisations, and the effects of PM were also investigated in relation to age group, seasonal variation and gender. Table 8 indicates the percentage change in IHD hospitalisations associated with a 10μg/m^3 increase in PM concentrations, across all seasons. A positive impact of PM was noticed in each group, except for the group with people greater than 85 years old. A larger effect was discovered among males and the 40-to-45-year age group, showing that age and gender may have an impact on the relationship between IHD admissions rate and PM. Particulate air pollution manifest higher ischaemic disease risk in male, this may be related to high exposure level of air pollution and tobacco smoking in men than women in China.

Variable	Frequency Distribution					Mean ±SD
	Minimum	25	50	75	Maximum	
All seasons						
Air pollutants (μg/m^3)						
PM_{10}	6	44.5	61	95	305	76.0±47.5
$PM_{2.5}$	8	30	46	70	255	56.3±38.6
OZONE	13	72	96	121	302	101.5±42.6
Weather conditions						
Temperature (˚C)	-4.2	6.1	15	22.2	31.3	14.1±9.2
Relative Humidity (%)	31.8	61.1	71.3	79.6	97.4	70.2±12.6
Cold season						
Air pollutants (μg/m^3)						
PM_{10}	6	53	76	120	305	70±44.6
$PM_{2.5}$	8	39	58	87	255	91.9±955.3
OZONE	13	60	78	100.5	206	81.4±29.7
Weather conditions						
Temperature (˚C)	-4.2	2.1	6	10.3	20.1	6.3±5.3
Relative Humidity (%)	31.8	59.8	69	76.8	97.4	68.2±13.2

Table 8: Summary of daily air pollutants and weather conditions in Shanghai in 2013-2014 [1].

Tam, et al. [9] conducted a time series study to determine the daily numbers of hospital admissions and IHD mortalities that can be attributed to daily concentrations of PM_{10} and $PM_{2.5}$ in Hong Kong. Daily numbers of mortalities between 2001 and 2010 were gathered via the known Death Microdata Set, from the statistics and census department. Daily numbers of emergency hospital admissions due to IHD were collected from 'seventeen acute hospitals' within the hospital services of Hong Kong. The concentrations of PM_{10} were monitored at all the thirteen monitoring stations while $PM_{2.5}$ was monitored at three monitoring stations. Data regarding hourly concentrations of PM_{10} and $PM_{2.5}$ were collected during a ten-year period from the Environmental Protection Department. Table 9 shows the relative risk of hospital admissions and IHD per 10µg/m^3 increase in concentration for PM_{10} and $PM_{2.5}$. Significant RR was noticed for PM_{10} and $PM_{2.5}$, ranging from 1.012 to 1.018 per 10µg/m^3 for mortality and 1.008 to 1.015 per 10µg/m^3 for hospital admissions.

IHD	NO_2	PM_{10}	$PM_{2.5}$	O_3	SO_3
Mortality	1.024	1.012	1.018	1.008	1.032
Best lag day	0-5	0-5	0-5	5	0-5
Hospital	1.021	1.08	1.05	1.06	1.019
Admissions					
Best lag day	0-4	-5	0-5	0-5	0-3
Remark *. p<0.01, **. P<0.01					

Table 9: Relative risks (95% confidence limits) of IHD mortality and hospital admissions per 10µg/m^3 increase in concentration of air pollutants [9].

Ye, et al. [4] carried out a study to examine the association between severe PM exposure and CHD (IHD) incidence in people aged above 40 years in Shanghai, China. Daily CHD (IHD) concentrations during 2005 and 2012 were identified from emergency department and outpatient department visits. Daily concentrations of PM_{10} were obtained over the eight-year period while daily concentrations of $PM_{2.5}$ were collected over a three-year period. Quasi-Poisson regression modelling was used to perform the analyses. Table 10 shows that high exposure to PM_{10} and $PM_{2.5}$ was associated with increased risk of CHD (IHD) emergency department and outpatient department visits. A 10µg/m^3 increase in the two-day moving average concentration of PM_{10} and $PM_{2.5}$ was associated with 0.74% and 0.23% in CHD (IHD) morbidity, respectively. The relationships appeared to be more apparent in the male and the elderly. Significant PM impacts were observed in the cold season, whereas, these were not statistically significant in the warm season.

	All seasons	Cold season	Warm season
CHD outpatients and emergency department visits (n)			
All	207.0±51.1	237.8±48.3	176.7±32.0
Male	92.4±24.9	107.0±24.1	78.0±15.5
Female	114.6±28.5	130.8±27.0	98.7±19.6
41-65 years	56.6±12.7	61.9±12.7	51.5±10.5
>65 years	150.4±43.7	175.9±42.3	125.2±27.4
PM_{10} (µg/m^3)	81.7±54.4	93.8±60.1	70.0±45.4
$PM_{2.5}$ (µg/m^3) [a]	38.6±26.7	48.7±29.3	28.9±19.5
Temperature (˚C)	17.4±9.1	9.7±5.6	25.0±4.3
Relative Humidity (%)	69.5±12.3	67.9±13.8	71.1±10.4
[a] $PM_{2.5}$ data was in 2009-2012			

Table 10: Summary (mean±SD) of daily CHD outpatient and emergency department visits, PM concentrations and weather conditions in Shanghai in 2005-2012 [4].

Face Mask and Particulate Matter Exposure

Langrish, et al. [6] made use of an open, randomised, crossover trial to investigate the benefits of reducing personal exposure to urban air pollution in patients with CHD (IHD). Ninety-eight patients were recruited from Fuwai hospital, Beijing, China. The patients were non-smokers with a history of CHD (IHD). They were instructed to walk on a predefined route in Beijing, under different conditions: once covered with a face mask and once not covered with a face mask. During the 24-hour study period, personal air pollution exposure, blood pressure, heart rate, symptoms and electrocardiography were recorded.

Langrish, et al. [6] found that the mask intervention reduced self-reported general symptoms, as shown in Figure 1. Table 11 shows that when a face mask was used, PM exposure reduced from 89µg/m^3 and 43,900 particles/cm^3 to 2µg/m^3 and 1,200 particles/cm^3.

Parameter	Mask	No Mask
Personal $PM_{2.5}$ exposure (µg/m^3)		
Measured	61(20-88)	89(25-170)
Estimated	-2(0.6-2.6)	89(25-170)
Personal particle count (x 10^{4}particles/cm^3)		
Measured	4.19±1.29	4.39±1.45
Estimated	- 0.12±0.04	4.39±1.45
Personal temperature (˚C)	17.3±5.2	16.8±5.8
Personal relative humidity (%)	30.4±14.0	34.8±18.2
Personal peaks >1ppm (number)		
NO_2	None	None
SO_2	None	None
CO	5(2-7.5)	4(2-8)
Background exposure		
PM_{10} (µg/m^3)	92(70-117)	103(83-180)
SO_2 (ppb)	38(29-53)	54(32-77)
NO_2 (ppb)	36(29-42)	36(32-47)

Table 11: Personal ambient pollution exposures and background pollution levels on days defined according to mask use [6].

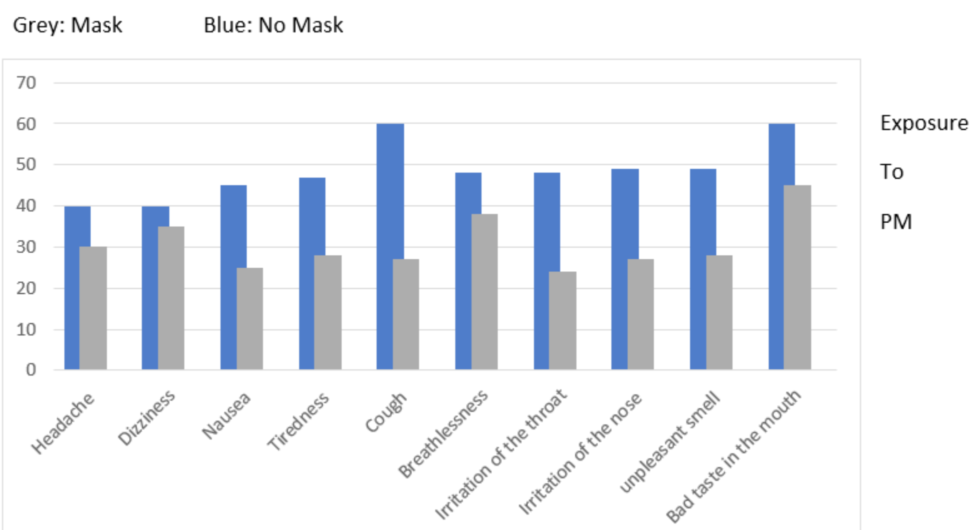

Figure 1: Self-reported symptoms of well-being in the presence or absence of the face mask [6].

Discussion

There is a growing interest in the relationship between PM and IHD. This narrative review provides robust evidence of the association of PM with IHD. Xie, et al. [10] found that the dose-response relationship between PM and IHD is non-linear, with a steeper dose-response function at lower concentrations and a shallower one at higher concentrations. Pope, et al. [12] found out that this result is consistent with the findings of a study conducted during winter in London, between 1958 and 1972. Then, it was discovered that a rise in air pollution was related to an increased risk of mortality, and the exposure-response association was non-linear across the full range of exposures and diminished at the higher level of exposures. Xie, et al. [10] report that the investigation of the dose-response relationship between PM and IHD is necessary to determine the extent of the adverse response. The discovery that an increase in $PM_{2.5}$ at a very low level was enough to produce a significant adverse reaction that impacted IHD mortality and morbidity suggests that there is no threshold for protection of $PM_{2.5}$ pollutions. They also found that, at higher $PM_{2.5}$ concentrations, the risk for IHD continues to rise as the particulate component increases, indicating that there is no saturation effect for the risk of IHD. This finding should encourage policy makers to act immediately in relation to reducing PM exposure.

Ye, et al. [4] found that elevated exposure to PM_{10} and $PM_{2.5}$ was associated with increased risk of IHD outpatient department and emergency department visits in a short duration of time. Pun, et al. [8] observed a positive relationship between PM_{10} and IHD hospitalization. Xu, et al. [1] also discovered that hospitalisation of IHD was strongly related with short-term exposure to elevated levels of PM_{10} and $PM_{2.5}$. These findings are consistent with the results of a study conducted in Taipei, Taiwan. Chiu, et al. [13] provided evidence in their study that short-term and long-term exposure to PM increases the risk of hospital admissions for IHD. They found a 4% increase in hospitalisation for IHD per 10μg/m^3 increment in $PM_{2.5}$ concentrations. A study by Dominic, et al. [14], that involved 204 counties across the United States, reported an association of 0.44% (95% CI 0.02% -0.86%) increase in risk of IHD admissions per 10μg/m^3 increase in $PM_{2.5}$. These findings established the possible role of PM in emergency department visits and hospital admissions for IHD.

It has been reported in several studies that some groups of subjects are prone to the unhealthy effects activated by PM exposure. Xie, et al. [10] discovered a significant association between PM and IHD mortality and morbidity among people ≥ 65 years. A study that was carried out in Shanghai by Xie, et al. [10] also find a stronger association between PM and IHD in people ≥ 65years than in younger people. Age is a risk factor for most cardiovascular disease and so it is logical that older people are more susceptible to particulate air pollution. These findings suggest that older people suffer most from elevated PM and should stay at home when PM concentration is too high. Several studies have reported on the role that weather plays in the association between PM and IHD. Xu, et al. [3] found that PM_{10} had a stronger effect on IHD mortality in summer compared to other seasons. Li, et al. [11] discovered that PM_{10} had similar effects both in the cool and warm seasons. Xu, et al. [1] found that PM concentration increased across all season. Ye, et al. [4] observed that significant effects of PM concentration were discovered in the cold season whereas these effects were not statistically significant in the warm season. The authors found conflicting evidence relating to the role of weather in PM concentration in Chinese cities. More research is needed in this area to explore the role that different seasons play in PM concentration.

Langrish, et al. [6] demonstrated that reducing personal exposure to PM by using a face mask is associated with an improvement in objective measures of myocardial ischemia, self-reported symptoms, blood pressure, and variability in patients with IHD. The findings of this study are supported in a later study carried out by Xie, et al. [7] who found that the use of a face mask helps to reduce symptoms and improve a range of cardiovascular measures in patients with IHD. Patients with IHD who are working, visiting and living in urban or industrialised environments can make use of a face mask to reduce their exposure to PM and the reduce the incidence of cardiovascular episodes. The health consequences of PM_{10} and $PM_{2.5}$ air pollution cannot be disregarded in the prevention of IHD. The Chinese government should make an effort to reduce or prevent IHD. They should focus on encouraging behavioural modification and target the implementation of appropriate measures to reduce PM_{10} and $PM_{2.5}$ exposures, especially for susceptible people living in areas with harmful PM_{10} and $PM_{2.5}$ concentration levels.

Key Messages

There is a growing interest in the association between Particulate Matter and Ischaemic Heart Disease in China. The purpose of this narrative review is to investigate this relationship. Ischaemic Heart Disease contributes immensely to the disease burden in Chinese cities, findings from this review will enable policy makers to make informed decision that will bring solution to this problem.

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