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# Short-term effects of fine particulate matter on acute myocardial infraction mortality and years of life lost: A time series study in Hong Kong

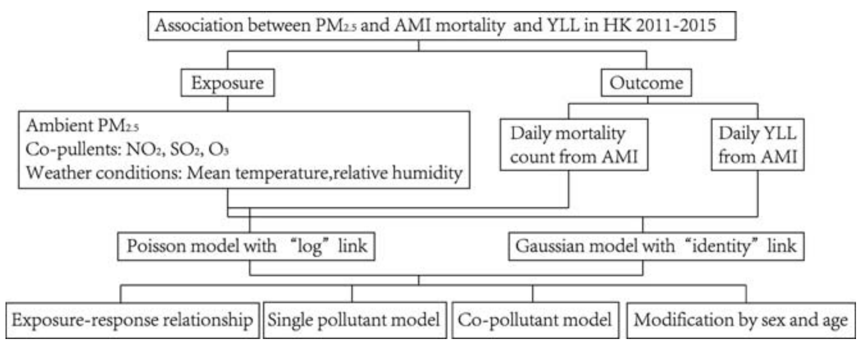
Haiqing Liang, Hong Qiu, Linwei Tian *

*School of Public Health, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong Special Administrative Region*

## HIGHLIGHTS

- First study to evaluate the association between $PM_{2.5}$ and YLL from AMI.
- Generalized Additive Poisson and Gaussian regression models were applied.
- Acute exposure to $PM_{2.5}$ was positively associated with mortality and YLL from AMI.
- Age and gender may modify the effect of $PM_{2.5}$ on AMI mortality.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Previous studies have applied years of life lost (YLL) as a complementary indicator to assess the short-term effect of the air pollution on the health burden from all-cause mortality, but sparsely focused on individual diseases such as acute myocardial infraction (AMI). In this study, we aimed to conduct a time-series analysis to evaluate short-term effects of fine particulate matter ($PM_{2.5}$) on mortality and YLL from AMI in Hong Kong from 2011 to 2015, and explore the potential effect modifiers including sex and age by subgroup analysis. We applied generalized additive Poisson and Gaussian regression model for daily death count and YLL, respectively. We found that 10 μg/m$^3$ increment in concentration of $PM_{2.5}$ lasting for two days ($lag_{01}$) was associated with a 2.35% (95% CI 0.38% to 4.36%) increase in daily mortality count and a 1.69 (95% CI 0.01 to 3.37) years increase in YLL from AMI. The association between $PM_{2.5}$ and AMI mortality count was stronger among women and older people than men and young people, respectively. We concluded that acute exposure to $PM_{2.5}$ may increase the risk of mortality and YLL from AMI in Hong Kong and this effect can be modified by age and gender. These findings add to the evidence base for public health policy formulation and resource allocation.



## 1. Introduction

Cardiovascular disease (CVD) as the third leading cause of deaths in Hong Kong, accounted for 13.2% of all deaths in 2015; ischemic heart disease (IHD) as a major category was responsible for 66.6% of CVD deaths (Centre for Health Protection, 2017). Acute myocardial infraction (AMI), as an important manifestation of IHD (Wichmann et al., 2014), is

* Corresponding author at: School of Public Health, Li Ka Shing Faculty of Medicine, The University of Hong Kong, 7 Sassoon Road, Pokfulam, Hong Kong Special Administrative Region.

*E-mail address:* linweit@hku.hk (L. Tian).

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one of major public health concerns in Hong Kong and it is urgent to assess the burden of AMI and related risk factors.

Ambient air pollution is a large threat to public health in the world (WHO, 2016). Hong Kong is experiencing deteriorating air quality and the health impacts of air pollution might be even higher than those in the developing countries in South Asia (Wong et al., 2008). Fine particulate matter ($PM_{2.5}$), defined as atmospheric particulate matter with aerodynamic diameter ≤ 2.5 μm, is one of the principal air pollutants in Hong Kong. $PM_{2.5}$ is a mixture of various compounds including chemical and biological ingredients rather than a self-contained pollutant and is associated with a wide range of adverse health effects mainly including respiratory and cardiovascular diseases (Kim et al., 2015).

The short-term effects of $PM_{2.5}$ morbidity and mortality risk of AMI have been demonstrated in numerous epidemiologic research studies in the world (Lanki et al., 2006; Nuvolone et al., 2011; von Klot et al., 2011; Wang et al., 2015; Wang et al., 2016; Wichmann et al., 2014). However, the short-term effect may differ because of the varying exposure level, components and the characteristic of population in different geographic locations (HEI, 2010). No studies have been conducted in Hong Kong to examine the association between acute exposure to $PM_{2.5}$ and AMI mortality. Moreover, mortality count alone depicts only a partial story of disease burden. Years of life lost (YLL), taking premature deaths and the life expectancy at death into consideration, would be an important complementary index to reflect the health burden due to air pollution, which is significant for public policy making and health service planning (Guo et al., 2013). Yet, studies applying YLL to quantify the disease burden have been sparse so far (Guo et al., 2013; He et al., 2016; Lu et al., 2015; Zhu et al., 2017) and to the best of our knowledge the short-term effect of $PM_{2.5}$ on YLL from AMI and the potential effect modification by demographic factors such as sex and age have not been investigated.

We performed a time-series study to evaluate the short-term effect of fine particulate matter on mortality and YLL from AMI, from 2011 to 2015 in Hong Kong, and explored the potential effect modification by sex and age.

## 2. Materials and methods

### 2.1. Data collection

#### 2.1.1. Mortality data

Daily data on mortality due to AMI in Hong Kong from January 1, 2011 to December 31, 2015 were obtained from Hong Kong Census and Statistics Department (CSD). The anonymous records provided information such as sex, age, date of death, and underlying death cause which was coded according to the International Classification of Diseases, Tenth Revision (ICD-10). In this study, the daily mortality count from AMI (ICD-10: I21) was abstracted and stratified by sex and age group (≤65 and >65 years old). Since we only used aggregated data rather than individualised data in this study, ethics approval and consent from individual subjects were not required by our institute.

#### 2.1.2. YLL data

Life tables for Hong Kong population from 2011 to 2014 were obtained from Hong Kong CSD (Census and Statistics Department, 2015), which provided the life expectancy at every exact age for males and females respectively. Life table for the year 2015 was unavailable, so we used life expectancies in 2014 as a substitute to compute the YLL for 2015. YLL values were calculated by matching sex and age to the life tables and daily total YLL were calculated as the sum of YLL of all deaths due to AMI on the same day (Guo et al., 2013). The daily YLL data were also stratified by sex and age.

#### 2.1.3. Air pollution and meteorology data

Hourly monitoring data for $PM_{2.5}$, particulate matter with aerodynamic diameters < 10 μm ($PM_{10}$), sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$) and ozone($O_3$) in 14 monitoring stations were collected by the Hong Kong Environmental Protection Department from 2011 to 2015. Excluding three roadside stations and one general station on a remote island, we used the data of the remaining 10 general stations to represent the general population exposure on a regular basis. We calculated the twenty-four hour mean concentrations of $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$ and $O_3$ for each station first and then averaged over ten stations to represent the daily exposure levels of the whole population. The daily mean temperature and relative humidity during 2011–2015 were obtained from the Hong Kong Observatory.

### 2.2. Statistical analysis

#### 2.2.1. Spearman correlation

The correlation between air pollutants and meteorological conditions was evaluated by Spearman's rank correlation test.

#### 2.2.2. Association between $PM_{2.5}$ and daily mortality count for AMI

We applied generalized additive Poisson regression model to estimate the association between daily mortality count for AMI and daily concentration of $PM_{2.5}$. We applied smoothing spline functions to control for secular trend and seasonality in daily mortality count, daily mean temperature, and relative humidity ($Humidity_0$). To adjust for the immediate and delayed effects of temperature, daily mean temperature of the same day ($Tmean_0$) the moving average of lag 1–3 days ($Tmean_{1-3}$) were included in the multiple regression model. The day of the week (*DOW*) and public holidays (*Holiday*) as dummy variables were also included in the model. Following the methods in previous studies (Bell et al., 2008; Peng et al., 2008; Qiu et al., 2012), we applied degrees of freedom (*df*) of 7/year for the time trend, 6 for $Tmean_0$ and $Tmean_{1-3}$, and 3 for relative humidity. The basic model was:

$$\log(E(Y)) = \alpha + s(time, df = 7/\text{year} \times 5\ \text{years}) + s(Tmean_0, df = 6) + s(Tmean_{1-3}, df = 6) + s(Humidity_0, df = 3) + \beta_1 \times DOW + \beta_2 \times Holiday$$

where *E(Y)* represents the expected daily mortality count for AMI and *s(.)* the smoothing spline function for nonlinear variables. Residual plot and partial autocorrelation function (PACF) plot demonstrated the successful control for secular trend and seasonality. The association of daily mortality count for AMI with $PM_{2.5}$ over two days, which was the moving average concentration over the same day and the previous day ($lag_{0-1}$) was included as the main analysis; association of AMI with $PM_{2.5}$ over the same day ($lag_0$) and three days before ($lag_1$ to $lag_3$) was also examined. We first fitted single pollutant models for $PM_{2.5}$ and the other three air pollutants ($NO_2$, $SO_2$ and $O_3$) and then included pollutants in multiple regression models. To find out whether there is effect modification by sex and age, we also examined the pollution and disease association in the subgroups and calculated the 95% confidence interval (CI) for difference: $(\beta_1 - \beta_2) \pm 1.96\sqrt{SE_1^2 + SE_2^2}$, where $\beta_1$ and $\beta_2$ are the estimates for two subgroups and $SE_1$ and $SE_2$ are their standard errors respectively (Schenker and Gentleman, 2001).

#### 2.2.3. Association between $PM_{2.5}$ and daily YLL for AMI

We applied generalized additive Gaussian models to examine the association of $PM_{2.5}$ with YLL for AMI because daily YLL for AMI followed a normal distribution according to the previous studies (Guo et al., 2013; Zhu et al., 2017). In the current study, the distribution of YLL from AMI and the plot of model residuals showed that the normality was not violated (Fig. S1).

All statistical analysis was performed with the *mgcv* package in R software, version 3.4.0. The results were presented in percent excess risk of daily mortality count (ER %) or the increment in YLL for AMI per 10 μg/$m^3$ increase of $PM_{2.5}$.