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Acute exposure to fine and coarse particulate matter and infant mortality in Tokyo, Japan (2002–2013)

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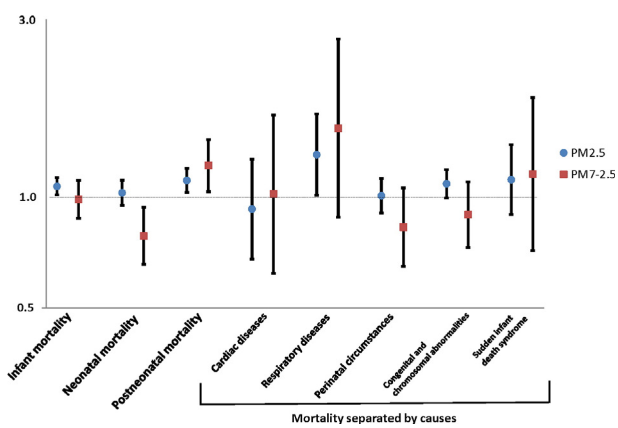
HIGHLIGHTS

- Evaluated associations between short-term exposure to PM and infant mortality
- We observed adverse effects of PM on infant mortality.
- $PM_{2.5}$ and coarse particles were independently associated with increased risk.
- Observed adverse health effects below Japanese air quality guidelines

GRAPHICAL ABSTRACT



Adjusted odds ratios and 95% confidence intervals following a 10 μ g/m³ increase in $PM_{2.5}$ and $PM_{7-2.5}$ on the event day for mortality among infants in Tokyo's 23 wards, Japan, 2002–2013.

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ABSTRACT

Few studies have evaluated the effect of short-term exposure to particulate matter (PM) less than 2.5 μm in diameter ($PM_{2.5}$) or to coarse particles on infant mortality. We evaluated the association between short-term exposure to PM and infant mortality in Japan and assessed whether adverse health effects were observable at PM concentrations below Japanese air quality guidelines. We used a time-stratified, case-crossover design. The participants included 2086 infants who died in the 23 urbanized wards of the Tokyo Metropolitan Government between January 2002 and December 2013. We obtained measures of $PM_{2.5}$ and suspended particulate matter (SPM; PM < 7 μm in diameter) from one general monitoring station. As a measure of coarse particles, we calculated $PM_{7-2.5}$ by subtracting $PM_{2.5}$ from SPM. We then used conditional logistic regression to analyze the data. Same-day $PM_{2.5}$ was associated with increased risks of infant and postneonatal mortality, especially for mortality related to respiratory causes. For a 10 μg/m³ increase in $PM_{2.5}$, the odds ratios were 1.06 (95% confidence interval: 1.01–1.12) for infant mortality and 1.10 (1.02–1.19) for postneonatal mortality. $PM_{7-2.5}$ was also associated with an increased risk of postneonatal mortality, independent of $PM_{2.5}$. Even when $PM_{2.5}$ and SPM concentrations were below Japanese air quality guidelines, we observed adverse health effects. This study provides further

Abbreviations: ANS, autonomic nervous system; CI, confidence interval; ICD, International Classification of Disease; OR, odds ratio; PM, Particulate matter; PM_{10}, particulate matter less than 10 μm in diameter; $PM_{2.5}$, particulate matter less than 2.5 μm in diameter; $PM_{7-2.5}$, particulate matter more than 2.5 μm and less than 7 μm in diameter; SIDS, sudden infant death syndrome; SPM, suspended particulate matter; TMG, Tokyo Metropolitan Government; WHO, World Health Organization.

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Postneonatal mortality

evidence that acute exposure to $PM_{2.5}$ and coarse particles ($PM_{7-2.5}$) is associated with an increased risk of infant mortality. Further, rigorous evaluation of air quality guidelines for daily average $PM_{2.5}$ and larger particles is needed.

1. Introduction

A large number of epidemiological studies have shown the adverse effects of short- and long-term exposure to particulate matter (PM) air pollution in terms of adult mortality (Atkinson et al., 2014; Brook et al., 2010; Hoek et al., 2013; Ruckerl et al., 2011). However, relatively few studies have focused on infant mortality. A previous review on infant mortality concluded that the evidence regarding the overall association between PM and infant mortality was inconsistent. However, the review also suggested that there has been some consistent evidence for associations between PM and both postneonatal mortality and sudden infant death syndrome (SIDS) (Glinianaia et al., 2004). Indeed, some cohort and case–control studies evaluating the effect of geographical differences in PM have shown adverse effects on postneonatal mortality (Ritz et al., 2006; Woodruff et al., 2008; Woodruff et al., 1997; Woodruff et al., 2006). However, time-series and case-crossover studies evaluating the effect of short-term exposure to PM on infant mortality have yielded inconsistent results (Carbajal-Arroyo et al., 2011; Diaz et al., 2004; Ha et al., 2003; Hajat et al., 2007; Loomis et al., 1999; Scheers et al., 2011; Son et al., 2008; Tsai et al., 2006; Yang et al., 2006). For example, a recent multicity study in Latin America found a positive association between PM less than 10 μm in diameter (PM_{10}) and respiratory mortality among infants in one city (Santiago), but this was not found to be the case in the two other cities examined (São Paulo and Mexico City) (Romieu et al., 2012).

Moreover, most previous time-series and case-crossover studies on infant mortality adopted PM_{10} as an exposure indicator, and few evaluated the effect of short-term exposure to PM less than 2.5 μm in diameter ($PM_{2.5}$) or to coarse particles (Loomis et al., 1999). Coarse particles, defined as particles more than 2.5 and less than 10 μm in diameter, have recently been reported to have short-term adverse health effects independent of $PM_{2.5}$, mostly among adult populations (Adar et al., 2014).

We evaluated the association between short-term exposure to PM and infant mortality in Tokyo, Japan. We also evaluated whether adverse health effects were observable at PM concentrations below the Japanese air quality guidelines.

2. Methods

2.1. Study design and subjects

We used a time-stratified, case-crossover design. The case-crossover design uses cases only. For individual cases, exposure before the event (case period) is compared with exposure at a comparable control (or "referent") period. The design thus can be considered a case–control version of a crossover study and can adjust for time-invariant confounders (Janes et al., 2005). Time-stratified control (or "referent") selection is recommended to avoid time-trend bias and to ensure unbiased estimates from conditional logistic regression (Janes et al., 2005). For this reason, we selected control periods from days other than the case periods. The selected control periods were on the same days of the week and in the same months and years as the case periods. We selected three or four control periods (days) per case period.

We targeted infants (under 1 year old) who died between January 2002 and December 2013 in the 23 urbanized wards of the Tokyo Metropolitan Government (TMG) ($n = 2086$). The TMG region, the capital city of Japan, is located in the middle of Japan and is divided into three types of areas: 23 central urbanized wards, surrounding cities, and islands. The total population of the 23 wards of the TMG is 8,489,653, and the infant population is 61,328, according to the 2005 census. The geographical size of the 23 wards is 536.8 km^2. In 2013, the infant mortality rate per 1000 births was 2.1 in Japan overall and 2.0 in Tokyo's 23 wards (Ministry of Health, Labour and Welfare in Japan, 2013).

2.2. Air pollution data

We focused on $PM_{2.5}$ and suspended particulate matter (SPM). SPM includes all particulate matter with an aerodynamic diameter below 7 μm (PM_7). PM, especially $PM_{2.5}$, tends to be well mixed within regions (HEI Panel on the Health Effects of Traffic-Related Air Pollution, 2010), and many previous studies have used PM as a main indicator of exposure to air pollution. In Japan, PM_{10} is not measured, and SPM is used instead. We also assessed the effects of coarse particles ($PM_{7-2.5}$, calculated by subtracting $PM_{2.5}$ from SPM). $PM_{2.5}$ and SPM were measured at one general monitoring station in the study area (No. 143 in Online Fig. 1). This monitoring station has measured $PM_{2.5}$ since April 2001, which the reason the study period began in 2002. This is the only station that has measured $PM_{2.5}$ over the study period in Tokyo's 23 wards. Following the Air Pollution Control Act, Japan has two types of monitoring stations: general stations and roadside stations. General stations are not located near specific sources of air pollutants. They are located, for example, at elementary schools, municipal offices, and community centers. Roadside stations are located near roads in residential locations (Kashima et al., 2009). We considered the air pollution data measured at general stations to be relevant, because it should represent air pollution exposure among the general population. The general station we used is located about 12 km from the central point of the 23 wards. A 28-km buffer area around the station covers the entire area of the wards. To examine the representativeness of the selected monitoring station, we evaluated correlations between $PM_{2.5}$ and SPM measured at the station (No. 143) and SPM measured at the general monitoring station located closest to the central point of the 23 wards (No. 101 in Online Fig. 1).

In addition, we obtained the daily concentrations of four other pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide, and ozone) from the five general stations (No. 104, 109, 110, 114, and 120) across the 23 wards where all four of these pollutants were measured (Online Fig. 1). These five stations are considered representative of Tokyo's 23 wards, because, when a 15-km buffer is drawn around each of these stations, the entire area of the wards is covered. We calculated representative daily average concentrations of each air pollutant from the daily concentrations at each monitoring station. We obtained the daily air pollutant data from the Bureau of Environment of the TMG.

2.3. Infant mortality

The Ministry of Health, Labour and Welfare in Japan provided electronic data on all-cause deaths in Tokyo's 23 wards during the study period, stripped of names and addresses. The underlying causes of death were coded according to the International Classification of Diseases, Tenth Revision (ICD-10). We focused on infant mortality (occurring less than one year of age), neonatal mortality (occurring less than 28 days postpartum), and postneonatal mortality (occurring at least 28 days postpartum and less than one year of age), as well as mortality related to cardiac diseases (I10-99), respiratory diseases (J00-99), perinatal circumstances (P00-96), congenital and chromosomal abnormalities (Q00-99), and sudden infant death syndrome (SIDS) (R95).