Invited Commentary

Invited Commentary: Assessment of Air Pollution and Suicide Risk

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Suicide is a serious public health issue worldwide, with multiple risk factors, such as severe mental illness, alcohol abuse, a painful loss, exposure to violence, or social isolation. Environmental factors, particularly chemical and meteorological variables, have been examined as risk factors for suicide, but less evidence is available on whether air pollution is related to suicide. In this issue of the Journal, Bakian et al. (Am J Epidemiol. 2015;181(5):295–303) publish findings from a study that found a short-term increased risk of suicide associated with increased air pollution. This study bolsters a small body of research linking air pollution exposure to suicide risk. If the association between air pollution and suicide is confirmed, it would broaden the scope of the already large disease burden associated with air pollution.

Suicide is one of the leading causes of death worldwide (1) and was one of the top 10 causes of death in the United States in 2009 (2). Suicide is a serious public health burden in terms of the emotional suffering that families and communities experience and the economic costs. Understanding which factors influence the risk of suicide is helpful for suicide prevention. Suicide is a complex outcome that is influenced by many lifetime factors, including mental illness, alcohol abuse, previous and current social experiences, and genetic susceptibility (2). Environmental factors, particularly chemical and meteorological variables, have been examined as risk factors for suicide (3, 4). However, air pollution, one of the leading causes of the global disease burden (5–7), has been examined as a risk factor for suicide in only 3 studies (8–10). More research is needed to better understand whether the risk of suicide is related to air pollution.

In this issue of the Journal, Bakian et al. (11) publish results of a study that used a time-stratified case-crossover design to investigate the association between air pollution and short-term risk of suicide. Air pollution levels and constituents vary from day to day, for a variety of reasons, including traffic volume, forest fires, and the weather. Many previous studies from around the world have examined how short-term changes in pollution affect risk of cardiovascular and respiratory diseases, and in general they have shown relatively small but consistent increases in risk (12, 13). Other studies have demonstrated the biological plausibility of how the various toxins in air pollution can damage the cardiovascular and respiratory systems (14, 15). The small increases in risk create a large public health problem, as many millions of people are exposed to air pollution every day. If the association between air pollution and suicide is confirmed, it would broaden the already extensive burden of disease associated with air pollution (7).

The findings by Bakian et al. (11) add weight to the small body of literature on the association between air pollution and suicide. Here we discuss selection bias in stratum length and case-control days for the case-crossover study design, potential confounding, and error in the measurement of pollution exposure in air pollution epidemiology. In addition, we discuss how to interpret and confirm the evidence.

**SELECTION BIAS IN STRATUM LENGTH AND CASE-CONTROL DAYS**

Bakian et al. used the time-stratified case-crossover study design to examine short-term associations between air pollutant exposure and suicide (11). The authors matched the case and control periods by day of the week in the same month. This method is widely used to control seasonality and
Confounders related to individual characteristics (e.g., age, sex, and smoking) are also controlled by design. The time-stratified case-crossover design using fixed and disjointed time-strata (e.g., calendar month) avoids the “overlap bias” (18). There are many different methods for choosing control days relative to a case day. For example, using 28 days as the stratum length, we can match the case-control days by means of exclusion days (0–7 days) or by means of an interval (every 1–6 days) (see Web Figure 1, available at http://aje.oxfordjournals.org/). Matching the case-control days according to 6-day intervals is the same as matching by day of the week. It is not clear what combination of stratum length and selection of control days produces the most unbiased estimates.

Using simulated data, we examined bias in the risk estimate according to stratum length and the sampling of case-control days. In our simulation, the true relationship between exposure and outcome was $\beta = 0.1$. The simulated data included seasonality (modeled by a cosine function) and a day-of-the-week effect for both exposure and outcome. We examined 420 types of time-stratified case-crossover designs by combining stratum length and type of case-control matching (Figure 1). The results showed that, in general, the longer the stratum length, the greater the bias in exposure-response associations. Matching case-control days by means of exclusion of 1–5 days produced higher bias than matching via exclusion of 0 days and matching using an interval (every 1–6 days). Bateson and Schwartz (19) similarly found that control sampling with closely matched controls reduced the bias in exposure-response associations in the symmetrical bidirectional case-crossover design. The problem arises because of the correlation between the simulated exposure and season. When the simulated exposure is nonseasonal, there is no bias (Web Figure 2). The implication is that the time-stratified case-crossover design with a long stratum length may not successfully control for seasonality. Therefore, we suggest that Bakian et al. check the seasonal trend for air pollutants and use shorter stratum lengths to reanalyze their data using sensitivity analyses.

**POSSIBLE CONFOUNDING**

Bakian et al. controlled for the weather because many previous studies have shown an association between weather and suicide (3, 4, 20). As they pointed out (11), the focus of studies of environmental causes of suicide has been on weather rather than air quality. In their analyses, Bakian et al. adjusted for sunlight, ambient temperature (air and dew point), and air pressure (11). These models were fitted using a time-stratified case-crossover design to control for season, and case-control days were matched by day of the week to remove the influence of that predictor completely.

One weather variable that was not included was precipitation. Suicide rates may decrease on rainy days, although exactly why this would happen is not clear (3), and another study found a positive correlation between rainfall and suicide (21). What is more certain is that the concentrations of air pollutants decrease on rainy days because of “scavenging” (22). Because rainfall potentially predicts short-term suicide risk and definitely predicts short-term concentrations of air pollutants, there is a potential for rainfall to confound the association between air pollution and suicide. In Salt Lake County, Utah, rainfall would need to be extended to precipitation of all kinds (rain, sleet, and snow). We recommend adding precipitation to the model, potentially as a log-transformed variable given its skewness. To reduce the risk of overfitting, we recommend removing dew point temperature and air pressure but keeping air temperature and sunlight, which are more plausible social or biological pathways to suicide.

**MEASUREMENT ERROR IN POLLUTION EXPOSURE**

To examine the associations between air pollutants and health outcomes as in Bakian et al.’s study (11), many investigators have used daily air pollution data from 1 monitoring site or daily mean values from a network of sites, which may lead to measurement error for pollution exposure (23, 24). Random measurement error in air pollutant levels may bias the estimates of association towards the null (25, 26). Studies have shown that there is spatial variation in concentrations of outdoor air pollutants within cities and their surroundings (22, 27–29). Urban areas with high population density, high levels of vehicle traffic, and industrial emissions usually have higher concentrations of air pollutants. This means that using air pollutants from 1 monitoring site or averaged values from a network of sites may produce underestimation of the associations between air pollutants and health outcomes.

Recently, different techniques (for example, land-use regression models, integrated emissions meteorological models, proximity-based assessments, statistical interpolation, line dispersion models, and hybrid models combining personal or household exposure monitoring with one of the preceding methods) have been developed for predicting urban air pollution concentrations from fixed monitoring data (23). Some studies have used such predicted concentrations of air pollutants to estimate the health impacts of air pollution within cities (30–32).

It would be useful to interpolate the concentrations of air pollutants for each case of suicide using one of above methods. If the predicted spatial exposures to air pollutants were significantly more accurate than fixed monitoring exposures, they might improve our understanding of the association between air pollution and suicide.

**INTERPRETING EVIDENCE**

We should always be cautious when new associations are found using observational data. More research is needed on the biological pathway between air pollution and suicide. Independent studies that confirmed the association in other geographical locations would also add to the evidence. Investigators in such studies should consider including data on the location of the suicide (at home or outdoors), as this might help in clarifying any effects of adverse weather conditions such as low temperatures and rainfall.

Bakian et al. assessed the impact of air pollutants only on completed suicides, not on suicide attempts, because, they argued, suicide completions and attempts “share some risk factors (e.g., the presence of a psychiatric diagnosis) but also have different risk factors (e.g., sex, the presence of stressful
Figure 1. Mean estimates for exposure-response associations (•) from 1,000 simulated data sets, modeled via time-stratified case-crossover designs. A) Matching using an interval; B) matching using exclusion. Dashed line, true exposure-response association (β = 0.1). Bars, 95% credible intervals.
life events)” (11, p. 301). Actually, suicide death is only the tip of the iceberg. In the United States, the ratio between suicide attempts and suicide deaths is over 30:1 (2). Therefore, it is essential to also understand the association between air pollution and suicide attempts.

In conclusion, we congratulate and thank Bakian et al. for their valuable work (11). In future studies, investigators need to refine the exposure measurements, confounding control, and selection of stratum length and case-control days for the case-crossover design, examine the impacts of air pollutants on suicide attempts, and expand the research to other geographical areas, so that data analyses will move closer to the confirmatory end of the spectrum.

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