A Bayesian hierarchical approach for relating $PM_{2.5}$ exposure to cardiovascular mortality in North Carolina

Christopher H. Holloman
Steven M. Bortnick
Michele Morara
Warren J. Strauss
Battelle Memorial Institute
Catherine A. Calder
The Ohio State University

Abstract

Considerable attention has been given to the relationship between levels of fine particulate matter (particulate matter $\leq 2.5\mu m$ in aerodynamic diameter; $PM_{2.5}$) in the atmosphere and health effects in human populations. Since the U.S. Environmental Protection Agency began widespread monitoring of $PM_{2.5}$ levels in 1999, the epidemiologic community has performed numerous observational studies modeling mortality and morbidity responses to $PM_{2.5}$ levels using Poisson generalized additive models (GAMs). Although these models are useful for relating ambient $PM_{2.5}$ levels to mortality, they cannot directly measure the strength of the effect of exposure to $PM_{2.5}$ on mortality. In order to assess this effect, we propose a three-stage Bayesian hierarchical model as an alternative to the classical Poisson GAM. Fitting our model to data collected in seven North Carolina counties from 1999 through 2001, we found that an increase in $PM_{2.5}$ exposure is linked to increased risk of cardiovascular mortality in the same day and next 2 days. Specifically, a $10 - \mu g/m^3$ increase in average $PM_{2.5}$ exposure is associated with a 2.5% increase in the relative risk of current-day cardiovascular mortality, a 4.0% increase in the relative risk of cardiovascular mortality the next day, and an 11.4% increase in the relative risk of cardiovascular mortality 2 days later. Because of the small sample size of our study only the third effect was found to have $> 95\%$ posterior probability of being > 0. In addition, we compared the results obtained from our model to those obtained by applying frequentist (or classical, repeated sampling-based) and Bayesian versions of the classical Poisson GAM to our study population.