EDITORIAL

Cleaner Air, Bigger Lungs

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In the latter half of the 20th century, Los Angeles had, by many measures, higher levels of photochemical air pollutants than any other major city in the United States (Fig. 1). To address this problem, the California Air Resources Board and its partners became leaders in quantifying the health effects of air pollutants and in aggressively implementing pollution-control strategies.

Even with these actions, air-pollution levels remained high. In 1993, "Health Advisories" were issued on 92 days.[1] In that year, the prospective Children's Health Study was launched to examine the effects of air pollution on lung growth in children. Fourth-grade children were recruited from 12 communities in southern California with varying exposures to the pollutants of concern (ozone, nitrogen dioxide, and particulate matter). Repeated lung-function measurements were taken for these children for 8 years, the period of life during which the greatest growth of lung function occurs.

In this first cohort, children living in more polluted communities had lower cumulative lung growth during the follow-up period.[2] These results were important clinically because even modest reductions in attained lung function at maturity are predictive of respiratory disease, coronary heart disease, and reduced life expectancy.[3]

Of course, such an association does not prove causality. However, the case for a causal relationship can be strengthened by consistent evidence from repeated studies. To that end, Gauderman and his colleagues enrolled two additional cohorts of children from the Children's Health Study and found consistent associations between community air pollution and lung-function growth in the children recruited in 1993,[2] 1997,[4] and 2003.[5]

The consistency of findings in the three separate cohorts is compelling. Moreover, the investigators sought to minimize the potential for confounding by controlling for known individual and community predictors of lung-function growth. Nevertheless, unmeasured or imperfectly measured characteristics of these communities, such as differences in ethnic background or socioeconomic status, may have confounded these analyses and produced a false positive association.

Although lung-function growth and potential confounders were measured for each child, air-pollution exposures were based on community means. Such studies have been described as "semi-individual"[6] with respect to the exposure variables. Thus, these analyses could also have been influenced by differences in community characteristics not captured in the individual data. A community is more than the aggregate of individual characteristics.[7]

In this issue of the *Journal*, Gauderman et al.[8] examine the association between improvements in air quality and changes in lung-function growth from 11 to 15 years of age across these three cohorts of children. They show that 4-year growth in forced expiratory volume in 1 second (FEV_1) and forced vital capacity (FVC) improved as levels of air pollution (nitrogen dioxide and particulate matter with an aerodynamic diameter of <2.5 μm [$PM_{2.5}$] and <10 μm [PM_{10}]) declined in five of these communities.

This study provides corroborating information because the analyses are based on comparisons within communities and thus are not confounded by differences between communities. The potential confounders of these temporal comparisons are characteristics of the communities that changed during the period of study. Recall that, to be a confounder, a variable must be associated with both air-pollution levels and lung-function growth. The advantage of these complementary approaches is that characteristics of the communities are less likely to confound both spatial and temporal comparisons.

In the original Children's Health Study cohort design, communities were selected to represent extremes of exposure to particulate matter, nitrogen dioxide, and ozone air pollution. For example, in 1994 mean concentrations of $PM_{2.5}$ ranged from 31.5 μg per cubic meter (in Mira Loma) to 6.7 μg per cubic meter (in Santa Maria), and the nitrogen dioxide level ranged from 36.4 ppb (in Long Beach) to 2.7 ppb (in Lompoc).[9] Between 1994 and 2010, the period analyzed by Gauderman et al., changes in $PM_{2.5}$ and nitrogen dioxide levels within the five study communities approached the between-community differences in 1994. For example, the mean $PM_{2.5}$ level improved from 31.5 μg per cubic meter (1994–1997) to 17.8 μg per cubic meter (2007–2010) in Mira Loma, and the nitrogen dioxide level improved from 34.4 ppb (1994–1997) to 20.3 ppb (2007–2010) in Long Beach. Temporal changes in ozone, however, were modest.

These results suggest that the children born after air-pollution levels had declined in these communities had greater lung-function growth. These investigators had previously shown, in a relatively small number of children, that participants who moved out of the study area to cleaner communities had improved lung-function growth, whereas those who moved to more polluted communities had reduced growth.[10] This raises the possibility that some of the loss of lung function associated with exposure to air pollution is reversible.

In recent years, much of the research on the effects of community air pollution has focused on premature death and on clinical events such as myocardial infarctions or hospital admissions. Because these events occur primarily among older adults, there has been less interest in intermediate physiological (subclinical) measures. Nevertheless, there is growing awareness of the effects of early life events on the risk of adult-

Figure 1. Pollution in Los Angeles.
Los Angeles is shown in the late 1980s (Panel A) and in 2014 (Panel B).

Ted Spiegel/Corbis (Panel A), Ted Soqui/Corbis (Panel B)

onset chronic diseases. Reduced lung function is a powerful predictor not only of chronic respiratory disease in adults but also of chronic cardiovascular disease. The reported net deficits in lung function in children living in the more polluted communities may provide a partial explanation for the associations between air-pollution levels and mortality rates observed both in southern California[11] and nationally.[12]

Some have argued that the substantial improvements in air quality over the past 40 years are sufficient to protect public health and that there is little evidence to support more stringent standards. However, the current report and other studies suggest that further improvement in air quality may have beneficial public health effects.

Four decades ago, most Americans were exposed to much higher levels of air pollution than those observed today. At that time, it was difficult to find communities with little or no exposure, which limited the ability of investigators to determine a "no-effect level." With the improvements in air quality, observational studies can now assess the benefits of reductions in air-pollution exposure into the range below those historical levels. These new observational studies often show that there are health benefits associated with improvements in air quality even when the pollution levels are within a range previously thought to be safe.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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