CASE STUDY 1

Hiker Health: The Effects of O_3 and Other Pollutants on Pulmonary Function

by Barrett Rock

Mount Washington and the major peaks region in the White Mountains National Forest, NH, host some 60,000 hikers per year. During hot summer days this region is often impacted by elevated levels of ground-level ozone, suspended fine particles of soot, and acidic aerosols (droplets) of anthropogenic origin. The exposure to ozone, fine particulates and strong acidic aerosols pose a health threat to hikers.

One of the few studies of the impact of air quality, under ambient conditions was conducted on hikers engaged in day hikes on Mount Washington. This study of adult hikers was conducted during the summers of 1991 and 1992 by research scientists from the Harvard Medical School, the Harvard School of Public Health, and the Appalachian Mountain Club (AMC). The study evaluated the short term effects of exposure to ambient ozone levels, fine particulate matter ($PM_{2.5}$) and aerosol acidity, on lung function of healthy adults exposed while hiking at elevation.

Background

Mount Washington and all of the New England Region is downwind from major sources of air pollutants. Tropospheric ozone is the photochemical product of reactions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight and high temperatures. Due to Mount Washington's geographic location, it is subjected to frequent episodic ozone exceedances (both 1-hour 120 ppb and 8-hour 80 ppb) during warm summer months. The summer of 1991 was characterized by a greater number of hot days (at or above 90°F) than was 1992. Due to the connection between temperature/amount of sunlight and ozone formation, higher ozone levels characterized the summer of 1991 than the summer of 1992.

The AMC and the Mount Washington Observatory have been monitoring ozone levels along an elevational gradient (at the base of Mount Washington - elev. 1500 ft./480 m, and at the summit at 6288 ft./1910 m) since 1987. Average ozone exposures during the period of this study ranged from 21 to 74ppb.

Ozone concentrations on a given date may vary considerably with elevation. The base layer of the atmosphere (the troposphere – extending from ground level to 10-15km/6-9 miles above the Earth) is in contact with the surface, resulting in mixing. Because of this, the lowermost layer of the troposphere is called the mixing layer (figure 7.1). The mixing layer extends up to 1km (3,280') or more above the surface, and varies in thickness based on time of day. The tropospheric layer above the mixing layer is termed the "stable layer" (due to the limited amount of turbulence characterizing this layer), and extends to the top of the troposphere. Long-distance transport of air pollutants may occur at the boundary between the mixing and the stable layers, and thus, hiking above approximately 3000' may expose the hiker to elevated levels of ozone and other pollutants not encountered at lower elevations (figure 7.2).

The Study

The lung function of adult hikers was measured before and after hiking on Mount Washington during 74 days during the summers of 1991 and 1992. The mean hourly ozone levels at both base and summit stations during the time of day of most day hikes was at or slightly above 40ppb (Figure 7.2).

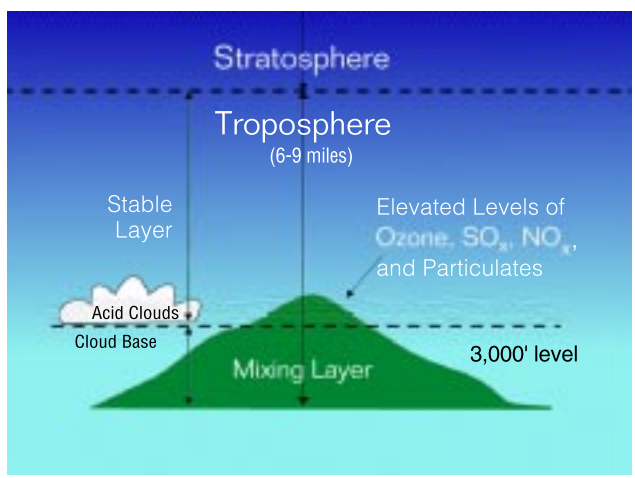

FIGURE 7.1 A diagrammatic representation of the mixing layer at the base of the troposphere, and the affect that elevation has on exposure to both acid cloud moisture and air pollutants.

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The effects of acute ozone exposure in humans are associated with decreased pulmonary (lung) function and can result in shortness of breath, coughing, and pain while inhaling. Controlled exposure studies associate ozone-exposure (80 - 400 ppb) to acute reduction in lung function and increased respiratory symptoms. Such chamber studies are often inconsistent when compared to natural settings and ambient ozone levels.

The Study Population

Volunteers were solicited from adult hikers (between 18 and 65) beginning a day hike at the trail entrance to AMC trails on the eastern slope of Mount Washington. During the summer months of 1991 and 1992, all hikers who volunteered were evaluated (n=766). Current non-smokers were evaluated in the final study (n=530), along with hikers with self-reported history of physician-diagnosed asthma or severe wheeze symptoms (n=40), and former smokers (n=125).

The Findings

Post-Hike percentage of change was determined and adjusted for hiker age, sex, smoking status (former vs. never), health history (asthma or wheeze), hours hiked, carrying a backpack, reaching the summit, and ambient temperature. It was found that for Every 50 ppb increment in mean ambient O_3 there was a 2.6% decline in forced expiratory volume (FEV_1); 2.2% decline in forced vital capacity (FVC), and a 4-fold greater response (15% reduction) in hikers with a history of asthma or wheeze. Former smokers exhibited increased sensitivity to a lesser degree than those with a history of asthma or wheeze.

The results presented in this hiker health study indicate that the effects of ozone exposure were greater than have been described previously in either field studies or controlled exposure chamber studies. These results are surprising, especially since average ozone exposure levels were relatively low (approximately 40ppb), one third of the current EPA ambient air quality standard (1-hour exposure to 120ppb ozone). These findings suggest that chronic exposure (8-hours duration) to low levels of ozone may be as damaging to pulmonary function as acute (short-term) exposure to higher levels of ozone. Finally, these results raise the concern that suppposely healthful exercise in the great outdoors may actually be hazardous to our health.

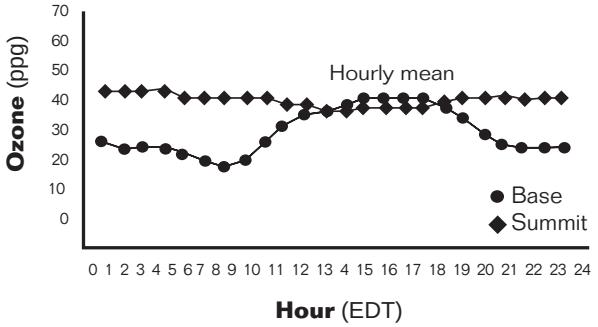

FIGURE 7.2 Mean hourly ozone levels (ppb) at the summit and base of Mt. Washington for the 74 days on which hikers were evaluated in summer 1991 and 1992. Note the pattern of the base station hourly mean ozone levels (elevated in the afternoons) and the lack of such a pattern at the summit .

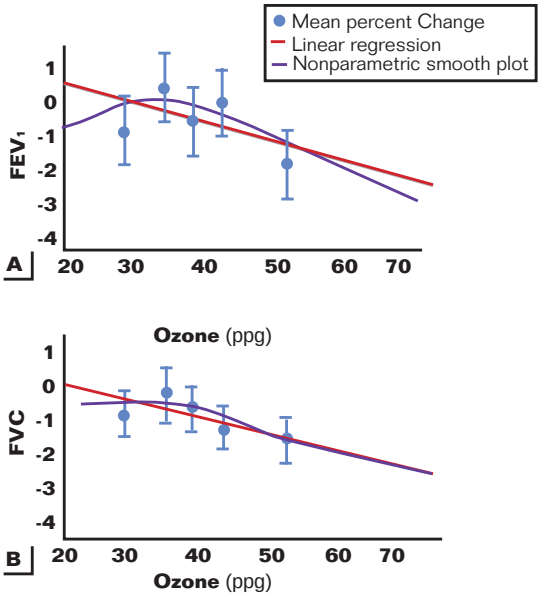

FIGURE 7.3 Posthike percentage changes in (A) forced expiratory volume in 1 sec (FEV_1) and (B) forced vital capacity (FVC) versus mean O_3 exposure after adjustment for age and other factors.