BLOOD LEAD CONCENTRATIONS AND GASOLINE LEAD USAGE

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ABSTRACT

Data from the NHANES II survey have been used to imply that the decrease in gasoline lead usage has been responsible for the surveyed decrease in blood lead. Statistical analyses of the NHANES II data indicate that the major part of the decrease in blood lead during the survey period was not due to the decline in gasoline lead usage. Other factors that could have contributed to the blood-lead decline include the impact of the nationwide blood-lead screening program, lead paint control and educational programs, and reduced lead content in processed food and beverages.

INTRODUCTION

The Second National Health and Nutrition Examination Survey (NHANES II) (ref 1) was conducted by the U.S. National Center for Health Statistics over the 4-year period of 1976-80. This survey was designed to obtain health and nutrition data on a sample of the U.S. population.

Venipuncture blood-lead concentration data were obtained for 9,933 persons in 64 sampling areas, including preschool children ages 6 months -5 years, youths ages 6-17 years, and adults ages 18-74 years (ref 2). All age groups included both sexes, whites and blacks, urban and rural groups, and several income levels. It should be emphasized that there was no repetitive sampling of any of the 64 areas or subjects. Thus, the survey was not designed as a longitudinal study to examine blood-lead trends with time. However, during the 4-year period of the survey, it was reported (ref 2, 3) that the overall mean blood-lead levels decreased about 37%, from 15.8 µg/dl to 10.0 µg/dl, with approximately the same percentage decrease for the different groups.

A partial summary of these blood-lead data was issued in March 1982 (ref 3). This included a chart showing the similarity of the decrease in average blood-lead levels and national gasoline lead usage with time. The scales used for the chart were adjusted to make the slopes of blood lead and gasoline lead usage as nearly identical as possible. The summary then concluded: "The decrease in mean blood-lead levels reflects the decrease in lead used in gasoline production."

This paper summarizes the results of statistical analyses of the NHANES II data.

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STATISTICAL ANALYSES OF NHANES II DATA

Preliminary analyses of the data showed that there was a sampling bias to fewer children and fewer non-rural residents during the latter period of the survey (see Figures 1 and 2). Both of these factors could affect the trend toward lower blood-lead levels. Linear regression of these parameters with time showed that the correlation coefficients with time of the variables of blood lead, gasoline lead usage, and percent children less than 6 years old were essentially equal. Rather than concluding that the decrease in gasoline lead usage caused the decrease in blood-lead level, one could equally well conclude that the decrease in blood-lead level was a result of the decrease in percent children in the sample less than 6 years old. Furthermore, the 33% reduction in blood-lead levels from 1976 to 1980 in the rural population was almost twice the 19% reduction in the urbanized population of greater than 1,000,000. The reverse should be true if the decline in vehicle lead emissions was a major factor in the blood-lead reductions.

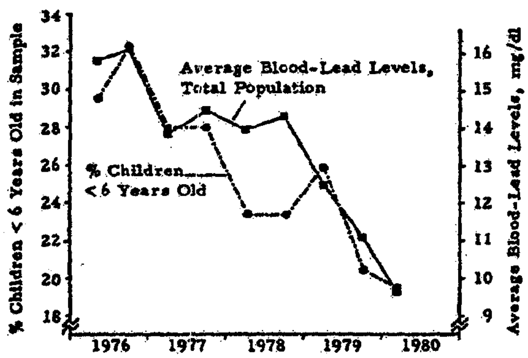

Figure 1. NHANES II Data

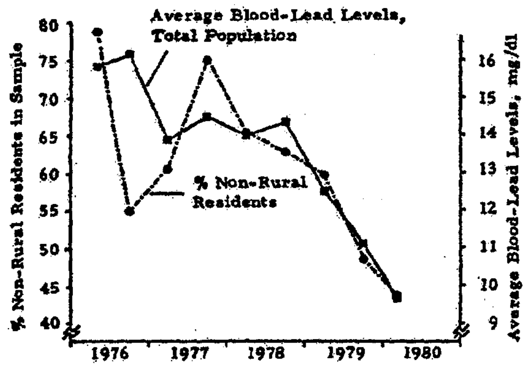

Figure 2. NHANES II Data

The preliminary analyses showed that sex, race, age, family income, and general location (urban vs non-urban) were significant independent variables affecting blood-lead concentration. Since there was a need to reduce or eliminate the confounding of these variables, we designed a regression model to separate the contributions to blood lead into those factors relating to personal attributes and those factors relating to the environment in which the person lived. A basic premise is that a specific individual's blood-lead content will respond to outside influence in the same manner wherever he lives. The extension of this premise is that, to explain the variations of blood-lead content, one must describe the environment in which the individual exists. Heretofore, the confounding effects between the personal descriptors and the environmental descriptors have clouded any attempts to understand the cause-effect relationships for the individual. By discrete-type regression techniques, these two contribution types have been separated for the NHANES II data so that the personal descriptors and environmental descriptors are essentially independent of each other. The personal descriptors are not subject to further analysis, but the environmental descriptors can be analyzed and/or correlated with any desired quantities related to outside factors that might affect the blood-lead content of an individual.

Monthly gasoline usage data are published for each state with subdivisions for leaded premium and regular gasolines for the period of the NHANES II data. During this period, limited sampling of leaded fuel for lead content provides gasoline lead concentrations. Combinations of gasoline usage and the lead concentrations then provide estimates of gasoline lead usage on a state basis. Thus, our objective was to relate the environmental descriptors to the available gasoline lead usage data.

The following independent variables were selected in an attempt to relate the blood lead of an individual to his exposure to lead.

Population Density -- Blood leads are known to respond to the air-lead concentration. Air-lead concentration data at the time of blood-lead sampling are not available for most NHANES II locations. Gasoline lead usage would be expected to be highly correlated with population density. Thus, population density can be used as an estimate of the relative air-lead exposure.

Gasoline Lead Usage -- Lead fallout from the atmosphere has been speculated to contribute to blood-lead concentration through the food chain. There is no method by which the individuals in the NHANES II study can be accurately related to this lead fallout-diet lead variable. The lead fallout contribution was estimated by dividing the gasoline lead usage for a state by the square miles of area.

Time -- Blood-lead concentrations have generally decreased with time because of reduction of lead in food packaging, paint, and other potential diet sources. Thus, time is a potential independent variable to represent lead from all sources, rather than gasoline lead alone, as contributors to blood lead.

A linear regression of the external contribution to blood-lead concentration (dependent variable) for each location was made with the independent variables of time, natural logarithm of the population density, and lead usage for each location. The natural logarithm of the population density was used because the range of these values spanned three orders of magnitude. Linear representation of population density would have placed excessive weighting on the high numbers.

The regression analysis showed that both time and population density were significant variables and the gasoline lead usage per area was an insignificant variable. The time variable was the major contributor to changes in blood lead, while population density was a minor contributor.

Using this model, blood-lead concentrations were calculated for three blood-lead-concentration groups--maximum, median, and low--in areas of low population density (10 persons/sq. mile) and high population density (3000 persons/sq. mile). These data can be used to estimate two responses:

1. The difference in blood-lead concentration between the high and low population densities.

2. The difference in blood-lead concentration from the beginning to the end of the survey period.

For 1976, the differences in blood leads between the high and low population densities range from 1.3 to 2.8 μg/dl, with an average of 2.1. For 1980, the differences in blood leads between the high and low population densities range from 0.9 to 2.1 μg/dl, with an average of 1.5. The average blood leads of the two population density groups are 18.7 μg/dl in 1976 and 13.5 μg/dl in 1980. If we assume that gasoline lead has the same percent contribution to blood lead relative to other sources in 1980 as in 1976, the 0.6 μg/dl decrease from 2.1 to 1.5 is due to population-related factors alone. Therefore, it must be the maximum possible reduction in blood lead due to the air-lead aspect of gasoline lead usage. The 5.2 μg/dl decrease in blood lead from 1976 to 1980 cannot be attributed to gasoline lead usage.

Air-lead concentration data are available from the National Air Sampling Network for 24 of the NHANES II locations for the quarter in which the blood-lead sampling occurred. Air-lead concentrations ranged from 0.14 to 1.84 $\mu g/m^3$ and cover the four years of the NHANES II study. The indicated response of blood-lead concentration to inhaled air lead is about 1 μg/dl per 1 $\mu g/m^3$. The apparent contribution of air lead to the NHANES II subjects appears consistent with this indicated response.

SUMMARY

The analyses that we have carried out, using population density as an indication of gasoline lead exposure for each of the 64 individual sampling locations, indicate that lead in gasoline accounts for less than 1 μg/dl of the reported 5.8 μg/dl decline in blood-lead level during the four-year period of the survey. Other factors that could have contributed to the reported decline in blood-lead levels include the impacts of lead-in-paint control programs, reductions in lead content of canned foods and beverages, reductions in lead released from ceramic glazes, and the educational efforts on lead hazards.

REFERENCES

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