ICF INTERNATIONAL

MEMORANDUM

To: Dan Axelrad, EPA

From: Jonathan Cohen, ICF

Date: 21 March, 2010

Re: CAHPD WA 1-03: Selected statistical methods for testing for trends and comparing years or demographic groups in ACE NHIS and NHANES indicators.

Introduction and Summary

America's Children and the Environment (ACE) brings together, in one place, quantitative information from a variety of sources to show trends in levels of environmental contaminants in air, water, food, and soil; concentrations of contaminants measured in the bodies of mothers and children; and childhood diseases that may be influenced by environmental factors. The ACE results have been published in two printed reports and also on a website http://www.epa.gov/envirohealth/children/ that is updated annually. The 2003 edition of ACE and the current ACE website includes indicators for body burdens of lead, mercury, and cotinine (the latter of which reflects exposure to environmental tobacco smoke), using data from the National Health and Nutrition Examination Survey (NHANES). For childhood illnesses associated with environmental contaminants, ACE includes indicators of the prevalence of asthma and neurodevelopmental disorders using data from the National Health Interview Survey (NHIS). NHANES and NHIS are both complex surveys conducted on a continuous basis by the National Center for Health Statistics in the Centers for Disease Control and Prevention. Both surveys provide high quality nationally representative data over a long period with detailed demographic information in addition to the detailed health data. Most of the data from both surveys are publicly available, although some data elements are masked to protect confidentiality. For the forthcoming third edition of ACE (ACE3), EPA plans to develop additional children's health indicators using data from NHANES and NHIS. The current presentation of indicators in ACE includes providing time series data and values stratified by race/ethnicity and family income, but does not include evaluation of whether the trends and differences are statistically significant. A goal for ACE3 is to add this type of statistical evaluation to the presentation of the indicators. The goal of the statistical methods presented in this memorandum is to be able to determine which of the observed trends and differences are large enough to be highlighted in discussions about the findings rather than being attributed to random variation.

This memorandum presents methods we intend to apply to statistical analysis of NHIS and NHANES data to address these three questions:

1. Is there a trend in the indicator value over time?
2. Is there a statistically significant change in the indicator value for a given year (or other time period) compared with the previous year?
3. Is there a statistically significant difference in the indicator value between different demographic groups?

The term “indicator value” refers to prevalence of a disease within a defined population, or to a percentile in the distribution of body burdens within a defined population.

This memorandum therefore describes various statistical methods for testing for trends, analyzing year-to-year changes, and comparing demographic groups in the values of the ACE indicators that use the NHIS and NHANES data. For the indicators from NHIS, logistic regression was selected, so that the logit of the prevalence (i.e., the logarithm of the odds of having the disease or condition) is regressed against the covariates. For the indicators from NHANES, weighted linear regression was selected, so that the percentile value is regressed against the covariates, inversely weighting each percentile by its estimated variance. In both cases the unadjusted analysis is compared to an analysis that adjusts for possible confounding effects by including other demographic variables in the regression. We also analyze the trends and year-to-year changes for different demographic groups, to evaluate whether the trend is different for different demographic groups. These methods were selected after considering several alternative approaches, taking into account comments received from internal and external reviewers and considering the feasibility of large scale application of these approaches to numerous ACE indicators.

The proposed methods for testing for trends and year-to-year changes are illustrated for NHIS using the 1997 to 2008 trends in the prevalence of being ever diagnosed with asthma and having an asthma attack in the last 12 months, and, for NHANES, using the 1988 to 2008 trends in the median blood lead of children ages 1 to 5. The proposed methods for comparing demographic groups are illustrated for NHIS using demographic group breakdowns in the 2005-2008 prevalence of being ever diagnosed with asthma and having an asthma attack in the last 12 months, and, for NHANES, using the 2005-2008 medians of blood lead in children ages 1 to 5 for different demographic groups.

National Health Interview Survey (NHIS)

Since 1957, the National Center for Health Statistics, a division of the Centers for Disease Control and Prevention, has conducted the National Health Interview Survey (NHIS), a series of annual US national surveys of the health status of the non-institutionalized civilian population. Data are collected by personal household interviews. Interviewers obtain information on personal and demographic characteristics, including race and ethnicity, by self reporting or as reported by an informant for children under 18 years of age. Investigators also collect data about illnesses, injuries, impairments, chronic conditions, activity limitation caused by chronic conditions, use of health services, and other health topics. For most health topics, the survey collects data over an entire year. The NHIS sample currently includes over-samples of Black, Hispanic, and Asian persons and is designed to allow the development of national estimates of health conditions, use of health services, and health problems of the U.S. civilian non-institutionalized population. The publicly released data includes survey weights to adjust for the over-sampling, non-response, and non-coverage. The ACE indicators use the sample child survey weights to re-adjust the data to represent the national population of children. SUDAAN statistical software for analyzing survey data was used to calculate variances and p-values accounting for correlations within clusters.

The following analyses use the ACE indicators of asthma prevalence. The indicators are derived from these questions in the NHIS: “Has a doctor or other health professional ever told you that <child’s name> had asthma?” (CASHMEV) and if yes, “During the past 12 months, has <child’s name> had an episode of asthma or an asthma attack?” (CASHYR). The combination of these responses gives the prevalence of being ever diagnosed with asthma and having an asthma attack in the last 12 months. Indicator D1 presents the data as a time series of asthma prevalence, using NHIS responses on an annual basis. Indicator D2 presents asthma prevalence by race/ethnicity and income, using a composite of the four most recent years of NHIS responses. The four-year composite is used to increase the statistical reliability of the estimates.

National Health and Nutrition Surveys (NHANES)

Since the 1960s, the National Center for Health Statistics, a division of the Centers for Disease Control and Prevention, has conducted the National Health and Nutrition Examination Surveys (NHANES), a series of US national surveys of the health and nutrition status of the non-institutionalized civilian population. Interviewers obtain information on personal and demographic characteristics, including age, household income, and race and ethnicity by self-reporting or as reported by an informant. Samples of blood, serum, and urine are collected in Mobile Examination Centers and analyzed for numerous chemical contaminants. The NHANES use a complex multi-stage, stratified, clustered sampling design. Certain demographic groups were deliberately over-sampled, including Mexican-Americans and Blacks. The publicly released data includes survey weights to adjust for the over-sampling, non-response, and non-coverage. The statistical analyses use the laboratory survey weights to re-adjust the concentration data to represent the national population. SUDAAN statistical software for analyzing survey data was used together with SAS software in order to calculate variances and p-values accounting for correlations within clusters.

The following analyses use the ACE indicators of childhood blood lead. The indicators are derived from NHANES blood lead measurements in children ages 5 and under. NHANES III (1988-1994)[1] and the NHANES 1999-2000, 2001-2002, 2003-2004, 2005-2006 and 2007-2008 surveys each included blood lead data for children aged 1 to 5 years. Indicator B1 presents the data as a time series of median and 95th percentile childhood blood lead levels, using measurements from each NHANES cycle. Indicator B2 presents median childhood blood lead levels by race/ethnicity and income, using a composite of the four most recent years of NHANES measurements. The four-year composite is used to increase the statistical reliability of the estimates.

The two national surveys NHANES and NHIS both have complex multi-stage designs, with stratification, clustering, and survey weighting. The strata are large geographical regions that contain the smaller PSU regions. In both cases, the public release versions provide pseudo-strata and pseudo-primary sampling units (PSUs). The samples can be treated as if from each stratum, a random sample of PSUs were drawn, and then several subjects were selected from each selected PSU. An important statistical difference between the two surveys is that the annual estimates from the NHIS surveys are not independent, because the NHIS survey samples from the same strata and PSUs for each year in the ten-year design period, but the NHANES biannual estimates are independent, because NHANES samples from different strata

[1] NHANES III was conducted over two three-year phases, Phase 1 from October 1988 to October 1991 and Phase 2 from September 1991 to October 1994. The survey design was chosen so that each phase was nationally representative, although the data from the two phases were not statistically independent. For the trend analyses each NHANES III Phase was analyzed as a separate period. For these trend analyses we have chosen not to include the data from NHANES II (1976-1980) for several reasons. The main reason is that we are interested in more recent trends. Including NHANES II would lead to a much stronger observed trend in blood lead that does not represent the more recent trends. Since the trend models assume a constant change in the percentile from year to year, that assumption will not be realistic if the early observed trend is much steeper than later trends. In addition, the NHANES II survey included fewer body burden chemical contaminants than the later surveys, so that most analyses of body burdens of interest will not be able to include the very early NHANES data; however, a similar comment applies to the NHANES III data.

each period[2]. This statistical difference impacts the recommended procedures for analyzing trends and year-to-year changes. Another relevant difference for ACE is that the NHIS ACE measures are prevalence rates but the NHANES ACE measures are percentile values. Because of these differences, the recommended procedures are not the same for the NHIS and NHANES measures.

In the next eight sections we will describe the methods used in more detail. In the first four of those sections we will describe the NHIS statistical analyses of trends, year-to-year changes, and demographic group differences using the example of asthma attack prevalence. In the second four sections we will give the corresponding statistical methods and results for the NHANES statistical analyses using the example of blood lead medians. The analyses were performed using SAS and SUDAAN statistical programming languages[3].

NHIS Measures - Trend Estimation and Year-to-Year Changes

<u>Trend Estimation</u>

We will illustrate the proposed approach using the 1997 to 2008 data for the annual prevalence of being ever diagnosed with asthma and having an asthma attack in the last 12 months. The same methods can be applied for analyzing trends over a shorter or longer period. For NHIS, in general, the data for different years are statistically dependent.[4]

For the 1997 to 2005 NHIS data, the strata were numbered from 1 to 339. For 2006 and later, the strata were numbered from 1 to 300. However, because a new sample design was developed for 2006 and later, stratum 1 in 1997 to 2005 is a different geographical region to stratum 1 in 2006 (similarly for strata 2 to 300), so that to properly analyze the NHIS data, it is necessary to distinguish the strata in 1997 to 2005 from the same numbered strata in 2006. Otherwise, the statistical analysis would incorrectly treat all the data from the stratum numbered 1 as having being selected from the same statistical stratum, and similarly for other stratum numbers, which would lead to incorrect estimates of the variances and p-values, although the annual statistics would not be affected. For this reason, 1,000 was added to the original stratum numbers for the year 2006; instead of 1,000, any number that avoids overlaps between the 1997 to 2005 stratum numbers and the new stratum numbers for 2006 could also have been chosen.

The asthma attack prevalence data for all demographic groups combined, stratified by year, are shown in Table 1. Table 1 also includes the standard errors of the estimated prevalence.

Table 1. Percentage of children ever diagnosed with asthma and having an asthma attack in the last 12 months, by year, for 1997-2008.

Year	Asthma Attack Prevalence (%)	Standard Error (%)
1997	5.46	0.22
1998	5.33	0.24

[2] The statistical independence of the NHANES periods applies to the selection of the random samples but may not apply to the corresponding US populations. Also, as noted above, the data for the two three-year phases of NHANES III are not statistically independent.
[3] SAS Version 9.1.3 and SAS-callable SUDAAN Version 10.0.1 were used for these statistical analyses. The software code is available by request.
[4] Note that the NHIS estimates for 1997 to 2005 are statistically dependent because the sample design (strata and primary sampling units) was the same for that entire period. A new sample design was developed for the 2006 (and later) NHIS surveys, which are therefore independent of the earlier surveys. Thus as a special case, the 2006 to 2008 estimates are independent of the estimates for 1997 to 2005.

Year	Asthma Attack Prevalence (%)	Standard Error (%)
1999	5.28	0.24
2000	5.54	0.23
2001	5.73	0.25
2002	5.77	0.27
2003	5.46	0.24
2004	5.45	0.25
2005	5.21	0.23
2006	5.56	0.30
2007	5.20	0.29
2008	5.61	0.32

The proposed statistical test for trend tests whether the prevalence is constant from year to year using a logistic model. The logarithm of the odds for year y is equal to log(p/(1-p)) = logit(p), the logit function, where the prevalence, p, depends upon the year, y. If the log odds are all equal, then logit(p) must be the same for all years, so that the prevalence is constant.

The logistic model has the general formulation

Logit {Prob(asthma attack for child c)} = function of explanatory variables for child c.

In general this function can be any parametric function of the child's explanatory variables, such as age, other demographic variables, state, county, other questionnaire variables, etc. These variables can be numerical variables or categorical variables. Categorical variables are represented by dummy indicator variables, one for each level. For example, for the categorical variable gender, this is a linear combination of the indicator I_b that equals 1 for boys and 0 for girls, and the indicator I_g that equals 1 for girls and 0 for boys.[5]

Unadjusted Test for Trend

The unadjusted test for trend is based on fitting the logistic trend model

Logit {Prob(asthma attack for child c in year y)} = Intercept + Trend $\times$ Year,

and then testing that the parameter Trend equals zero.[6] Note that in this formulation, year is assumed to be a numerical variable. Under the null hypothesis, Trend equals zero, so that the logits are equal for every year, which implies that the prevalence is constant. Under the alternative hypothesis, the logit of the prevalence is either increasing or decreasing as the year increases, which implies that the prevalence is either increasing or decreasing. This model assumes that the logit of the prevalence increases or decreases by the same amount each year.

Since NHIS is a complex survey with stratification, clustering, and weighting, and is not a simple random sample, the logistic modeling should take the survey design into account. For example,

[5] To avoid an over-parameterized model, if there is an intercept, then the coefficient for the last category can be set to be zero, so that in effect the last category is not used in the regression model. Thus for gender we only need the I_b indicator.

[6] To avoid some numerical convergence problems, a centering constant of 1990 was subtracted from the numerical value for year before fitting the logistic model. This modification has no mathematical effect on the estimated Trend parameter, its standard error, or its p-values, but the values for the Intercept parameter are changed accordingly. The same subtraction of 1990 from the year value was applied to all the logistic regression models for the trend and year-to-year changes described in this memorandum.

in NHIS, the same geographical strata were used for each year from 1995 to 2005 and for each year from 2006 onwards, so that data from different years are not statistically independent. This logistic modeling for complex survey data can be performed using the SUDAAN procedure RLOGIST. For these analyses, and all the logistic regression analyses described in this memorandum, we use the SUDAAN test statistic WALDF, which is for the Wald F test, described as follows.

SUDAAN versions 9.0.3 and later offers five alternative test statistics that are all based on the Wald Chi-square statistic Q and the denominator degrees of freedom, df, calculated as the number of PSUs minus number of strata in the survey design. In addition to the default Wald F test, using Q/df, the alternative test statistics give better approximations to the distributions of the test statistic if the denominator degrees of freedom, df, is small (e.g., less than 50). The test statistics are given by the SUDAAN keywords:

WALDCHI:	Wald Chi-Square test using the Wald Chi-square statistic Q.
WALDF:	Wald F test using Q/df
ADJWALDF:	Adjusted Wald F test
SATADJCHI:	Satterthwaite-adjusted Wald Chi-square
SATADJF:	Satterthwaite-adjusted Wald F test

For NHIS data, the denominator degrees of freedom is large, 339, so that the default Wald F test is a reasonable choice, although the other test statistics will give very similar but slightly more accurate results. However, as described below, for most of the logistic regression modeling of the NHIS data, we include the income variable as a covariate or to stratify the data, and therefore used multiple imputation methods to treat cases where unreported income data is imputed (estimated from a statistical model). When multiple imputation methods are used, SUDAAN only offers the default Wald F test because the Satterthwaite adjustments are not applicable. Therefore, for consistency, we recommend using the default Wald F test for all the logistic regression models, whether or not they incorporate the imputed income variables.

The important assumption is given by the logistic trend model equation. One advantage is that the logistic model is easy to generalize. The unadjusted test for trend uses the above logistic trend model and tests whether Trend equals zero. This assumes that the calendar year is the only relevant factor.

<u>Adjusted Test for Trend</u>

An easy generalization is of the form:

$$\text{Logit}\ \{\text{Prob(asthma attack for child c in year y)}\} = \text{Intercept} + \text{Trend} \times \text{Year} + \text{g(demographic group)},$$

where the demographic group is a categorical explanatory variable, e.g., race/ethnicity or gender. In SUDAAN, the race/ethnicity model can easily be fitted by defining a classification variable RACE that has different values for different race/ethnicity groups, and writing the model terms as “race year”. Alternatively, dummy indicator variables can be created for each group, such as race1 = 1 if white, Non-Hispanic, race1= 0 otherwise, and the model terms are of the form “race1 race2 … racen year” Similarly for other demographic groupings.

Using this more general model, the p-value for Trend tests for a trend adjusted for the demographic variables. This would account for the possible confounding effects caused by changes in the demographics of the national populations between the years. For example, the ACE results have shown that black children have higher asthma rates than white children.

Suppose that the black children's population increased from one year to the next year, but the asthma rates remained constant for both groups. In this case, the overall asthma rate given by the value of Trend in the basic model would show an increase, but this increase would be due to the population demographic changes rather than changes in the disease prevalence itself due to other factors (e.g., air pollution). For this example, the value of Trend in the generalized model with an extra race variable would be zero. This shows that there would have been no trend in asthma prevalence had the race/ethnicity distributions remained the same from year to year. Note that this generalized model adjusts for changes in the demographics of the national population from year to year. The survey weights already adjust for changes in the demographics of the sample populations.

Although a wide variety of possible logistic regression models could be used to adjust for confounding, we restrict our modeling to a few basic models, which has practical advantages and also ensures consistency. We propose restricting the adjusted analysis to the following model formulation:

$$\text{Logit }\{\text{Prob(asthma attack for child c in year y)}\} =$$
$$\text{Intercept} + \text{Trend} \times \text{Year} + f(\text{age group}) + g(\text{gender}) + h(\text{race/ethnicity}) + k(\text{income})$$

This model adjusts for the confounding effects of age, gender, race/ethnicity, and income. Since this model adds separate terms for each demographic factor, we do not consider the possibility of interactions between the demographic and year factors, so that, for example, the effect of age on asthma is assumed to be the same for each year, gender, race, and income. Moreover, we propose to adjust for all four demographic factors, even if some or all of the terms f, g, h, and k are not statistically significant.

For analyses of asthma attack prevalence in children ages 17 and under, we propose the following categories:

Age groups

- <= 5 years
- 6-10 years
- 11-17 years

Gender groups

- Males
- Females

Race/ethnicity groups

- White, Non-Hispanic
- Black, Non-Hispanic
- Asian, Non-Hispanic
- Hispanic
- Other (includes multiple race, non-Hispanic respondents whose single or primary race was known and was neither White, Black, African-American, nor Asian, and unknown race).

Income groups

Using imputed income for cases where the reported income is missing and is replaced by estimated values:

- Below Poverty Level
- At or Above Poverty Level (or unknown)

Note that the Other race/ethnicity group includes those with a missing, unknown race. Although the ACE demographic breakdowns treat the unknown race group as a separate group from the other race group, we combined the other and unknown categories to avoid convergence problems caused by having a category with very few respondents.

For the income variable, there was a large percentage of respondents that did not report their family income. For those respondents, CDC used a statistical regression procedure to estimate the income variables based on other available information. These estimated values are called "imputed" values. Five sets of imputed values were randomly generated. The statistical analysis of these multiple imputations is described in the next subsection. Although reported or imputed income values were available for almost all respondents, there were a very small number for which neither the reported not the imputed income was available. To avoid convergence problems, we combined those missing income cases into the At or Above Poverty Level group.

A statistically significant adjusted trend would show that the asthma trend is statistically significant after adjusting for possible confounding effects of age, gender, race/ethnicity and income.

Multiple imputation

Approximately 30 percent of families did not report their exact family income. From 1997 to 2006, the majority of these families either reported their income as two categories (above or below $20,000) or as 44 categories. For 2007 and later, the income questions were revised, so that families not reporting an exact income were first asked to report their income as either above or below $50,000, and were then asked appropriate additional questions to refine the income range as either 0-$34,999, $35,000-$49,999, $50,000-74,999, $75,000-$99,999, or $100,000 and above. In 2007, 91 percent of families either gave the exact income or the two-category response.

NCHS reports[7] evidence that the non-response to the income question is related to person-level or family-level characteristics, including items pertaining to health. Therefore treating the missing responses as being randomly missing would lead to biased estimates. To address this problem, NCHS applied a statistical method called "multiple imputation" to estimate or "impute" the family income based on the available family income and personal earnings information and on responses to other survey equations. A series of regression models were used to predict the exact family income from the available responses. Five sets of simulated family income values were generated for each family that did not report their exact family income. In this manner, NCHS generated five data sets, each containing a complete set of family income values (either the reported or the imputed values). The poverty income ratio categories were calculated from the income values and the family size and composition variables.

[7] "Multiple imputation of family income and personal earnings in the National Health Interview Survey: methods and examples," http://www.cdc.gov/nchs/about/major/nhis/2007imputedincome.htm, August, 2008.

SUDAAN and other statistical software packages analyze the multiple imputations using methods described by Rubin and other authors.[8] Some references are provided at the end of this subsection. Using SUDAAN software, the logistic regression model is separately fitted to each of the five data sets. The overall set of regression coefficients is calculated as the arithmetic means of the regression coefficients from the five imputation data sets. The standard errors, tests and p-values are computed using the estimated variances between and within the five imputations, using the formulas in Barnard and Rubin (1999). This multiple imputation method is applied in all the logistic regression analyses of the NHIS data described in this memorandum.

Stratified Tests for Trend

The Adjusted Test for Trend accounts for the possibility that the overall trend might be partly due to changes in population demographics rather than changes in the overall asthma prevalence. However, another possibility to be considered is that the asthma trend might be different for different demographic groups, which is an example of a phenomenon called interaction. For example, an overall trend might be due to a strong trend for Blacks but a negligible trend for Whites. It is also possible that an increasing trend in one group is almost cancelled out by a decreasing trend in another group, producing a negligible overall trend. To investigate these possible interaction effects we propose a stratified analysis that separately tests for a trend in each demographic group. The proposed analysis adjusts for possible confounding by the other demographic groups.

The following logistic regression models are proposed, one for each demographic subset:

Adjusted trend test by age group

Logit {Prob(asthma attack for child c in age group a and year y)} =
Intercept + Trend × Year + g(gender) + h(race/ethnicity) + k(income)
(model fitted to children in age group a only)

Adjusted trend test by gender

Logit {Prob(asthma attack for child c in gender group g and year y)} =
Intercept + Trend × Year + f(age) + h(race/ethnicity) + k(income)
(model fitted to children in gender group g only)

Adjusted trend test by race/ethnicity

Logit {Prob(asthma attack for child c in race/ethnicity group r and year y)} =
Intercept + Trend × Year + f(age) + g(gender) + k(income)
(model fitted to children in race/ethnicity group r only)

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[8] Barnard, J. and Rubin, D.B. (1999), "Small-Sample Degrees of Freedom with Multiple Imputation," *Biometrika*, 86, 948 - 955.

Little, R.J.A. and Rubin, D.B. (2002), *Statistical Analysis with Missing Data*, Second Edition, New York: John Wiley & Sons, Inc.

Rubin, D.B. (1976), "Inference and Missing Data," *Biometrika*, 63, 581 - 592.

Rubin, D.B. (1987), *Multiple Imputation for Nonresponse in Surveys*, New York: John Wiley & Sons, Inc.

Rubin, D.B. (1996), "Multiple Imputation After 18+ Years," *Journal of the American Statistical Association*, 91, 473 - 489.

Adjusted trend test by income

Logit {Prob(asthma attack for child c in income group i and year y)} =
Intercept + Trend × Year + f(age) + g(gender) + h(race/ethnicity)
(model fitted to children in income group i only)

A statistically significant adjusted trend would show that the asthma trend in the particular demographic group is statistically significant after adjusting for the effects of the other demographic groups. These results will allow us to determine if the overall trend is consistent across the different demographic groups or if the trend is different (in magnitude or direction) for different demographic groups.

Year-to-Year Change

The second statistical issue is to test for year-to-year changes. Of interest is whether the change in asthma attack prevalence between the most current year and the prior year is statistically significant. For this issue, the proposed statistical approach is to apply exactly the same set of logistic regression analyses as the tests for trend, but restrict the analyses to the data from the last two years only. If the trend from the last two years is statistically significant, then the change from year-to-year must also be statistically significant. Note that the value of the Trend parameter will then equal the estimated annual change in the logit of the prevalence (after adjusting for any other demographic variables in the logistic regression model).

Results for Trends and Year-to-Year Changes in Asthma Attack Prevalence

These logistic regression tests were applied to the asthma attack data from NHIS. The trend test was applied to the trend over the period 1997 to 2008. The year-to-year change test was applied to the change from 2007 to 2008.

Table 2 shows the unadjusted prevalence proportions that are compared in each of the statistical tests. FROMYEAR and TOYEAR give the range of years analyzed. AGAINST is the variable of interest, which is year for the trend and year-to-year change tests. “race” is an abbreviation for “race/ethnicity.” SUBSET gives the demographic subset analyzed, if any. VALUE is the value of the variable of interest and PROPORTION is the asthma attack prevalence for that value (not adjusted for confounding). For example, rows 1-12 are for the trend analyses and give the prevalence proportions for each year (same as in Table 1), rows 13-24, for the trend analyses, gives the prevalence proportions for ages 5 and under for each year, and the last 22 rows, for the year-to-year comparisons, display the prevalence proportions for children at or above the poverty level.

Table 2. Proportion of children ever diagnosed with asthma and having an asthma attack in the last 12 months, by year and demographic group, for 1997-2008.

FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	PROPORTION
1997	2008	year		1997	0.055
1997	2008	year		1998	0.053
1997	2008	year		1999	0.053
1997	2008	year		2000	0.055
1997	2008	year		2001	0.057
1997	2008	year		2002	0.058

FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	PROPORTION
1997	2008	year		2003	0.055
1997	2008	year		2004	0.055
1997	2008	year		2005	0.052
1997	2008	year		2006	0.056
1997	2008	year		2007	0.052
1997	2008	year		2008	0.056
1997	2008	year	<= 5 years	1997	0.043
1997	2008	year	<= 5 years	1998	0.049
1997	2008	year	<= 5 years	1999	0.045
1997	2008	year	<= 5 years	2000	0.047
1997	2008	year	<= 5 years	2001	0.051
1997	2008	year	<= 5 years	2002	0.053
1997	2008	year	<= 5 years	2003	0.045
1997	2008	year	<= 5 years	2004	0.044
1997	2008	year	<= 5 years	2005	0.045
1997	2008	year	<= 5 years	2006	0.051
1997	2008	year	<= 5 years	2007	0.045
1997	2008	year	<= 5 years	2008	0.050
1997	2008	year	6-10 years	1997	0.060
1997	2008	year	6-10 years	1998	0.051
1997	2008	year	6-10 years	1999	0.057
1997	2008	year	6-10 years	2000	0.056
1997	2008	year	6-10 years	2001	0.066
1997	2008	year	6-10 years	2002	0.059
1997	2008	year	6-10 years	2003	0.057
1997	2008	year	6-10 years	2004	0.059
1997	2008	year	6-10 years	2005	0.065
1997	2008	year	6-10 years	2006	0.070
1997	2008	year	6-10 years	2007	0.054
1997	2008	year	6-10 years	2008	0.058
1997	2008	year	11-17 years	1997	0.061
1997	2008	year	11-17 years	1998	0.058
1997	2008	year	11-17 years	1999	0.056
1997	2008	year	11-17 years	2000	0.062
1997	2008	year	11-17 years	2001	0.056
1997	2008	year	11-17 years	2002	0.060
1997	2008	year	11-17 years	2003	0.061
1997	2008	year	11-17 years	2004	0.060
1997	2008	year	11-17 years	2005	0.049
1997	2008	year	11-17 years	2006	0.050
1997	2008	year	11-17 years	2007	0.057
1997	2008	year	11-17 years	2008	0.060
1997	2008	year	Males	1997	0.059
1997	2008	year	Males	1998	0.065
1997	2008	year	Males	1999	0.061
1997	2008	year	Males	2000	0.066
1997	2008	year	Males	2001	0.064
1997	2008	year	Males	2002	0.068

FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	PROPORTION
1997	2008	year	Males	2003	0.063
1997	2008	year	Males	2004	0.067
1997	2008	year	Males	2005	0.059
1997	2008	year	Males	2006	0.064
1997	2008	year	Males	2007	0.056
1997	2008	year	Males	2008	0.067
1997	2008	year	Females	1997	0.050
1997	2008	year	Females	1998	0.041
1997	2008	year	Females	1999	0.044
1997	2008	year	Females	2000	0.044
1997	2008	year	Females	2001	0.050
1997	2008	year	Females	2002	0.047
1997	2008	year	Females	2003	0.046
1997	2008	year	Females	2004	0.041
1997	2008	year	Females	2005	0.044
1997	2008	year	Females	2006	0.047
1997	2008	year	Females	2007	0.048
1997	2008	year	Females	2008	0.045
1997	2008	year	White, Non-Hispanic	1997	0.052
1997	2008	year	White, Non-Hispanic	1998	0.053
1997	2008	year	White, Non-Hispanic	1999	0.050
1997	2008	year	White, Non-Hispanic	2000	0.054
1997	2008	year	White, Non-Hispanic	2001	0.057
1997	2008	year	White, Non-Hispanic	2002	0.055
1997	2008	year	White, Non-Hispanic	2003	0.049
1997	2008	year	White, Non-Hispanic	2004	0.054
1997	2008	year	White, Non-Hispanic	2005	0.048
1997	2008	year	White, Non-Hispanic	2006	0.052
1997	2008	year	White, Non-Hispanic	2007	0.043
1997	2008	year	White, Non-Hispanic	2008	0.052
1997	2008	year	Black, Non-Hispanic	1997	0.068
1997	2008	year	Black, Non-Hispanic	1998	0.067
1997	2008	year	Black, Non-Hispanic	1999	0.075
1997	2008	year	Black, Non-Hispanic	2000	0.075
1997	2008	year	Black, Non-Hispanic	2001	0.077
1997	2008	year	Black, Non-Hispanic	2002	0.085
1997	2008	year	Black, Non-Hispanic	2003	0.080
1997	2008	year	Black, Non-Hispanic	2004	0.078
1997	2008	year	Black, Non-Hispanic	2005	0.066
1997	2008	year	Black, Non-Hispanic	2006	0.074
1997	2008	year	Black, Non-Hispanic	2007	0.081
1997	2008	year	Black, Non-Hispanic	2008	0.086
1997	2008	year	Asian, Non-Hispanic	1997	0.046
1997	2008	year	Asian, Non-Hispanic	1998	0.041
1997	2008	year	Asian, Non-Hispanic	1999	0.038
1997	2008	year	Asian, Non-Hispanic	2000	0.047
1997	2008	year	Asian, Non-Hispanic	2001	0.047
1997	2008	year	Asian, Non-Hispanic	2002	0.044

FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	PROPORTION
1997	2008	year	Asian, Non-Hispanic	2003	0.039
1997	2008	year	Asian, Non-Hispanic	2004	0.021
1997	2008	year	Asian, Non-Hispanic	2005	0.039
1997	2008	year	Asian, Non-Hispanic	2006	0.048
1997	2008	year	Asian, Non-Hispanic	2007	0.037
1997	2008	year	Asian, Non-Hispanic	2008	0.032
1997	2008	year	Hispanic	1997	0.051
1997	2008	year	Hispanic	1998	0.047
1997	2008	year	Hispanic	1999	0.045
1997	2008	year	Hispanic	2000	0.042
1997	2008	year	Hispanic	2001	0.040
1997	2008	year	Hispanic	2002	0.044
1997	2008	year	Hispanic	2003	0.044
1997	2008	year	Hispanic	2004	0.041
1997	2008	year	Hispanic	2005	0.053
1997	2008	year	Hispanic	2006	0.052
1997	2008	year	Hispanic	2007	0.058
1997	2008	year	Hispanic	2008	0.040
1997	2008	year	Other	1997	0.064
1997	2008	year	Other	1998	0.038
1997	2008	year	Other	1999	0.075
1997	2008	year	Other	2000	0.075
1997	2008	year	Other	2001	0.080
1997	2008	year	Other	2002	0.073
1997	2008	year	Other	2003	0.120
1997	2008	year	Other	2004	0.080
1997	2008	year	Other	2005	0.074
1997	2008	year	Other	2006	0.055
1997	2008	year	Other	2007	0.057
1997	2008	year	Other	2008	0.104
1997	2008	year	Below Poverty Level	2001	0.065
1997	2008	year	Below Poverty Level	2002	0.076
1997	2008	year	Below Poverty Level	2003	0.068
1997	2008	year	Below Poverty Level	2004	0.064
1997	2008	year	Below Poverty Level	2005	0.061
1997	2008	year	Below Poverty Level	2006	0.070
1997	2008	year	Below Poverty Level	2007	0.065
1997	2008	year	Below Poverty Level	2008	0.069
1997	2008	year	At or Above Poverty Level	1997	0.055
1997	2008	year	At or Above Poverty Level	1998	0.053
1997	2008	year	At or Above Poverty Level	1999	0.053
1997	2008	year	At or Above Poverty Level	2000	0.055
1997	2008	year	At or Above Poverty Level	2001	0.056
1997	2008	year	At or Above Poverty Level	2002	0.054
1997	2008	year	At or Above Poverty Level	2003	0.051
1997	2008	year	At or Above Poverty Level	2004	0.052
1997	2008	year	At or Above Poverty Level	2005	0.050
1997	2008	year	At or Above Poverty Level	2006	0.052

FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	PROPORTION
1997	2008	year	At or Above Poverty Level	2007	0.049
1997	2008	year	At or Above Poverty Level	2008	0.053

Table 3 gives the results of the statistical tests for whether the trend or year-to-year difference is statistically significant. The columns FROMYEAR, TOYEAR, AGAINST, and SUBSET are the same as for Table 2. The column TYPE is "trend" for the trend tests and "year-to-year" for the year-to-year comparisons. The column ADJUST lists the demographic variables used to adjust for confounding, if any. BETA shows the logistic regression coefficient of year, and thus is the estimated annual change in the logit of the prevalence. The column PVAL gives the p-value of the statistical test, so that p-values less than 0.05 are statistically significant at the 5 percent significance level. In this memorandum, results will be referred to as statistically significant if they are significant at the 5 percent level. For example, from row 1, we can see that the annual change in the logit for the unadjusted trend test is −0.00025, which is not statistically significant (p-value = 0.954), and from row 2, we can see that the annual change in the logit for the trend test adjusted for age, gender, race and income is −0.00557, which is also not statistically significant (p-value = 0.222). Rows 3 to 5 give the trend analyses for different age groups. For ages <= 5 years and ages 11-17 years, the prevalence is decreasing, but the prevalence is increasing for ages 6-10 years. At the five percent level, these trends are not statistically significant for any of these age groups. The 2007 to 2008 year-to-year change was not statistically significant overall (unadjusted or adjusted), but there was a statistically significant decrease from 2007 to 2008 for Hispanics and a statistically significant increase for Other race/ethnicities.

Table 3. Statistical significance tests comparing the trends and year-to-year changes in the proportions of children ever diagnosed with asthma and having an asthma attack in the last 12 months, for 1997-2008.

TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	ADJUST	BETA	PVAL
trend	1997	2008	year			-0.00025	0.954
trend	1997	2008	year		age gender race income	-0.00557	0.222
trend	1997	2008	year	<= 5 years	gender race income	-0.00803	0.351
trend	1997	2008	year	6-10 years	gender race income	0.00756	0.345
trend	1997	2008	year	11-17 years	gender race income	-0.01372	0.060
trend	1997	2008	year	Males	age race income	-0.00519	0.388
trend	1997	2008	year	Females	age race income	-0.00614	0.420
trend	1997	2008	year	White, Non-Hispanic	age gender income	-0.01060	0.086
trend	1997	2008	year	Black, Non-Hispanic	age gender income	-0.00032	0.975
trend	1997	2008	year	Asian, Non-Hispanic	age gender income	-0.01935	0.457
trend	1997	2008	year	Hispanic	age gender income	0.00250	0.800
trend	1997	2008	year	Other	age gender income	0.01544	0.532
trend	1997	2008	year	Below Poverty Level	age gender race	-0.00825	0.665
trend	1997	2008	year	At or Above Poverty Level	age gender race	-0.00563	0.229
year-to-year	2007	2008	year			0.07952	0.355
year-to-year	2007	2008	year		age gender race income	0.07820	0.370
year-to-year	2007	2008	year	<= 5 years	gender race income	0.12817	0.420
year-to-year	2007	2008	year	6-10 years	gender race income	0.06898	0.649
year-to-year	2007	2008	year	11-17 years	gender race income	0.04978	0.707
year-to-year	2007	2008	year	White, Non-Hispanic	age gender income	0.20957	0.127
year-to-year	2007	2008	year	Black, Non-Hispanic	age gender income	0.07179	0.664

TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	ADJUST	BETA	PVAL
year-to-year	2007	2008	year	Asian, Non-Hispanic	age gender income	-0.16837	0.688
year-to-year	2007	2008	year	Hispanic	age gender income	-0.38438	0.033
year-to-year	2007	2008	year	Other	age gender income	0.66491	0.043
year-to-year	2007	2008	year	Below Poverty Level	age gender race	0.08297	0.662
year-to-year	2007	2008	year	At or Above Poverty Level	age gender race	0.07759	0.461

NHIS Measures – Compare Demographic Groups

The third statistical issue is to test for differences in prevalence among demographic groups. In this case the analysis is restricted to a group of years, and the comparison is between the overall prevalence for that period in different demographic groups, such as for different age groups. Logistic regression modeling again is proposed. The same demographic group categories as the trend analyses are used. The asthma attack prevalence for 2005-2008 for each demographic group is tabulated in Table 4, using a similar format to Table 2.

Table 4. Proportion of children ever diagnosed with asthma and having an asthma attack in the last 12 months, by demographic group, for 2005-2008.

TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	PROPORTION
demographic	2005	2008	age		<= 5 years	0.048
demographic	2005	2008	age		6-10 years	0.062
demographic	2005	2008	age		11-17 years	0.054
demographic	2005	2008	gender		Males	0.061
demographic	2005	2008	gender		Females	0.046
demographic	2005	2008	race		White, Non-Hispanic	0.049
demographic	2005	2008	race		Black, Non-Hispanic	0.077
demographic	2005	2008	race		Asian, Non-Hispanic	0.039
demographic	2005	2008	race		Hispanic	0.051
demographic	2005	2008	race		Other	0.073
demographic	2005	2008	income		Below Poverty Level	0.066
demographic	2005	2008	income		At or Above Poverty Level	0.051
demographic	2005	2008	income	White, Non-Hispanic	Below Poverty Level	0.056
demographic	2005	2008	income	White, Non-Hispanic	At or Above Poverty Level	0.048
demographic	2005	2008	income	Black, Non-Hispanic	Below Poverty Level	0.089
demographic	2005	2008	income	Black, Non-Hispanic	At or Above Poverty Level	0.070
demographic	2005	2008	income	Asian, Non-Hispanic	Below Poverty Level	0.022
demographic	2005	2008	income	Asian, Non-Hispanic	At or Above Poverty Level	0.041
demographic	2005	2008	income	Hispanic	Below Poverty Level	0.060
demographic	2005	2008	income	Hispanic	At or Above Poverty Level	0.046
demographic	2005	2008	income	Other	Below Poverty Level	0.070
demographic	2005	2008	income	Other	At or Above Poverty Level	0.074

There is a wide variety of possible demographic comparisons that could be addressed using statistical tests. These statistical tests are intended to confirm or evaluate the patterns that we can see when comparing the prevalence percentages for different race and family income combinations as well as for other demographic subgroups. The results of these statistical tests can then be used to decide which differences should be highlighted in our discussions of the various NHIS indicators. In this memorandum we present statistical methods for the comparisons that we expect to be of interest for most of the NHIS indicators, but in some cases it may be necessary to use similar statistical methods for comparisons not considered here.

Unadjusted Test for Demographic Group Differences

Consider the case of testing for gender differences. The logistic regression model can be written in the general form:

Logit {Prob(asthma attack for child c)} = Intercept + g(gender)

This is an unadjusted model, since the possible confounding effects of other demographic variables are not accounted for. The test for no demographic differences tests that the overall gender effect defined by the function g(gender) is zero, which implies that the prevalence for boys is the same as the prevalence for girls.

It is probably easier to understand the model if it is rewritten using dummy indicator variables, using an intercept together with a linear combination of the indicator I_b that equals 1 for boys and 0 for girls, and the indicator I_g that equals 1 for girls and 0 for boys:

Logit {Prob(asthma attack for child c)} = Intercept + $bI_b + gI_g$

The test for no demographic differences tests if the two slope parameters b and g are equal. The alternative hypothesis is that b and g are not equal. In the full rank parameterization, g is set to equal zero, so that the null hypothesis is that b equals zero.

In a similar manner we propose tests for differences among age groups, among race/ethnicity groups, or among income groups. The general formulations are:

Logit {Prob(asthma attack for child c)} = Intercept + f(age); test f(age) = 0.

Logit {Prob(asthma attack for child c)} = Intercept + h(race/ethnicity);
test h(race/ethnicity) = 0.

Logit {Prob(asthma attack for child c)} = Intercept + k(income);
test k(income) = 0.

Adjusted Test for Demographic Group Differences

Just as for the trend test, it is possible that the overall differences could be confounded. For example, any difference (or lack of difference) between the prevalence for boys and girls might be partly attributable to differences between boys and girls in their population distributions of race/ethnicity and/or age group and/or income group, assuming that race/ethnicity and/or age group and/or income group also affect asthma prevalence. To adjust for the confounding effects, the following logistic regression model is proposed:

Logit {Prob(asthma attack for child c)} =
Intercept + f(age) + g(gender) + h(race/ethnicity) + k(income)

The same model is used for all four adjusted tests. As before, this model assumes that there are no interactions between the different demographic group effects.

Adjusted test for age: Test f(age) = 0.

Adjusted test for gender: Test g(gender) = 0.
Adjusted test for race/ethnicity: Test h(race/ethnicity) = 0.
Adjusted test for income: Test k(income) = 0.

Race/Ethnicity and Income Paired Comparisons.

The unadjusted and adjusted tests for race/ethnicity comparisons described in the last two subsections are each a broad test for whether there are any differences in prevalence among race/ethnicity groups or whether all the race/ethnicity groups have the same prevalence. If significant race/ethnicity differences are found overall, then we would like to use the statistical analysis to evaluate statements that say that one race/ethnicity group has a higher prevalence than another group or that one race/ethnicity group has the highest prevalence among all the groups. If the differences are statistically significant, then these statements are supported. Otherwise, the observed differences are small enough that are applicable to the sample but have not been shown to be applicable to the US population. For example, we can make a statistical comparison between the prevalence for the two groups White, Non-Hispanic and Black, Non-Hispanic. These specific comparisons are easily made using appropriately defined contrasts applied to the logistic regression model that tests whether the corresponding regression coefficients are equal.

Assume that the race/ethnicity groups are numbered 1 to 5 and that I_j is the dummy variable that equals 1 for members of group j and equals 0 otherwise. Then the unadjusted logistic regression model for race/ethnicity is of the form

$$\text{Logit \{Prob(asthma attack for child c)\}} = \text{Intercept} + h(\text{race/ethnicity}),$$

which is equivalent to the model

$$\text{Logit \{Prob(asthma attack for child c)\}} = \text{Intercept} + h(1)I_1 + h(2)I_2 + h(3)I_3 + h(4)I_4 + h(5)I_5$$

To compare groups j and k, the appropriate statistical test is of the null hypothesis h(j) = h(k), which tests the null hypothesis that the two groups have the same regression parameters, and hence the same predicted prevalence. This test is easily performed in SUDAAN using an effects contrast for this logistic regression model. For example, to compare groups 1 and 3, the contrast statement is coded as

```
effects race = (1, 0, −1, 0, 0);
```

A p-value is calculated for each pair of race/ethnicity groups. The same set of contrast comparisons are used for the adjusted model, with additional terms for age, gender, and income.

Since there are ten paired comparisons between the 5 race/ethnicity groups, there is a high probability that at least one paired comparisons will be found statistically significant even if there are no race/ethnicity differences in the asthma prevalence. While it is possible to make adjustments to the p-values to account for this multiple comparisons issue, we choose not to make an adjustment for multiple comparisons, but users of the results should be aware of the increased probability of an erroneous statistical decision when multiple comparisons are made.

As mentioned above, we would like to use the results to evaluate statements about the race/ethnicity group with the highest prevalence. For example, Table 4 shows that Non-Hispanic Black children had the highest asthma attack prevalence among the five race/ethnicity groups in

2005-2008. A statistical test for the specific alternative hypothesis that Non-Hispanic Black children had the highest asthma attack prevalence among the five race/ethnicity groups is not available. Instead we propose to examine the paired comparisons between the Black, Non-Hispanic group and each of the other four race/ethnicity groups and if we find that all the differences are statistically significant, then we can confirm that the Non-Hispanic Black children had the highest asthma attack prevalence among the five race/ethnicity groups since the differences are not attributable to random variation. As discussed in the last paragraph, we choose not to make an adjustment for the multiple comparisons.

In a similar manner, we want to evaluate statements about the income group with the highest prevalence (from Table 4, Below Poverty Level for asthma attack prevalence in 2005-2008) and about the combined race/ethnicity and income group with the highest prevalence (from Table 4, Black, Non-Hispanic and Below Poverty Level for asthma attack prevalence in 2005-2008). Since there are only two income groups, the unadjusted and adjusted tests for income differences already evaluate the first question. To evaluate the second question, we fit a logistic model with a term for raceincome, defined as the combination of race/ethnicity and income (10 categories):

Unadjusted raceincome model

Logit {Prob(asthma attack for child c)} = Intercept + q(race/ethnicity and income)

Adjusted raceincome model

Logit {Prob(asthma attack for child c)} =
Intercept + q(race/ethnicity and income) + f(age) + g(gender)

We then apply a similar set of contrasts to compare each pair of race/ethnicity/income groups. Note that in these models, the categorical variable q denotes the combination of race/ethnicity and income and so these two models include the possibility of an interaction between race/ethnicity and income, i.e., that the effect of race/ethnicity on asthma attack prevalence may vary with the income level.

Results for NHIS Tests on Demographic Group Differences in Asthma Attack Prevalence

Table 5 gives the results of the statistical tests for overall demographic group differences. Table 5 has the same format as Table 3 except that a BETA coefficient is not reported. The prevalence is statistically significantly different between different age groups, genders, race/ethnicity groups, and income groups overall, both using the unadjusted and adjusted models.

Table 5. Statistical significance tests comparing the proportions of children ever diagnosed with asthma and having an asthma attack in the last 12 months, by demographic group, for 2005-2008.

TYPE	FROMYEAR	TOYEAR	AGAINST	ADJUST	PVAL
demographic	2005	2008	age		0.001
demographic	2005	2008	gender		< 0.0005
demographic	2005	2008	race		< 0.0005
demographic	2005	2008	income		< 0.0005
demographic	2005	2008	age	gender race income	0.001
demographic	2005	2008	gender	age race income	< 0.0005

TYPE	FROMYEAR	TOYEAR	AGAINST	ADJUST	PVAL
demographic	2005	2008	race	age gender income	< 0.0005
demographic	2005	2008	income	age gender race	0.006

Table 6 gives the results of the paired comparisons between race/ethnicity groups and between race/ethnicity/income groups. The statistical models are defined as in Table 3 using the variables AGAINST, and ADJUST, and the column SUBSET defines the income subset, if any. (For easier formatting the TYPE, FROMYEAR, and TOYEAR columns are not shown here, since their values are all "demographic" "2005" and "2008"). For the pair of race/ethnicity or race/ethnicity/income groups defined in the RACEINC1 and RACEINC2 columns, the p-value for the contrast is given in the column PVAL.

For the overall unadjusted analyses, six of the 10 pairs of race/ethnicity groups had statistically significant differences at the five percent level: White, Non-Hispanic versus Black, Non-Hispanic; White, Non-Hispanic versus Other; Black, Non-Hispanic versus Asian, Non-Hispanic; Black, Non-Hispanic versus Hispanic; Asian, Non-Hispanic versus Other, and; Hispanic versus Other. The same sets of statistically significant findings applied to the adjusted analyses, although the p-values had some slight differences. As noted earlier, the Black, Non-Hispanic group had the highest prevalence. Examining the paired comparisons between Black, Non-Hispanic and the four other groups, the differences are significant except between Black, Non-Hispanic and Other, so we can confirm that the Black, Non-Hispanic group has the highest prevalence, although it is not significantly higher than the Other group, based on our statistical tests.

The analysis of the combined raceincome variable shows that the prevalence differences between Black, Non-Hispanic, < Poverty Level and each of the other race/ethnicity and income combinations are statistically significant (at the five percent level) for all cases except Other, < Poverty Level, Other >= Poverty Level, and Black, >= Poverty Level, both for the unadjusted and adjusted analyses. Although this group has the highest observed prevalence (see Table 4), we cannot confirm that the Black, Non-Hispanic below poverty level group has the statistically significantly highest prevalence, based on our statistical tests.

Table 6. Statistical significance tests comparing the proportions of children ever diagnosed with asthma and having an asthma attack in the last 12 months, between pairs of race/ethnicity and race/ethnicity/income groups, for 2005-2008.

AGAINST	ADJUST	RACEINC1	RACEINC2	PVAL
race		White, Non-Hispanic	Black, Non-Hispanic	< 0.0005
race		White, Non-Hispanic	Asian, Non-Hispanic	0.139
race		White, Non-Hispanic	Hispanic	0.630
race		White, Non-Hispanic	Other	0.005
race		Black, Non-Hispanic	Asian, Non-Hispanic	< 0.0005
race		Black, Non-Hispanic	Hispanic	< 0.0005
race		Black, Non-Hispanic	Other	0.777
race		Asian, Non-Hispanic	Hispanic	0.108
race		Asian, Non-Hispanic	Other	0.003
race		Hispanic	Other	0.014
race	age gender income	White, Non-Hispanic	Black, Non-Hispanic	< 0.0005
race	age gender income	White, Non-Hispanic	Asian, Non-Hispanic	0.144
race	age gender income	White, Non-Hispanic	Hispanic	0.937
race	age gender income	White, Non-Hispanic	Other	0.009
race	age gender income	Black, Non-Hispanic	Asian, Non-Hispanic	< 0.0005

AGAINST	ADJUST	RACEINC1	RACEINC2	PVAL
race	age gender income	Black, Non-Hispanic	Hispanic	< 0.0005
race	age gender income	Black, Non-Hispanic	Other	0.917
race	age gender income	Asian, Non-Hispanic	Hispanic	0.178
race	age gender income	Asian, Non-Hispanic	Other	0.004
race	age gender income	Hispanic	Other	0.012
raceincome		White, Non-Hispanic, < PL	Black, Non-Hispanic, < PL	0.004
raceincome		White, Non-Hispanic, < PL	Asian, Non-Hispanic, < PL	0.037
raceincome		White, Non-Hispanic, < PL	Hispanic, < PL	0.649
raceincome		White, Non-Hispanic, < PL	Other, < PL	0.465
raceincome		White, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.246
raceincome		White, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.119
raceincome		White, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.125
raceincome		White, Non-Hispanic, < PL	Hispanic, >= PL	0.172
raceincome		White, Non-Hispanic, < PL	Other, >= PL	0.144
raceincome		Black, Non-Hispanic, < PL	Asian, Non-Hispanic, < PL	0.002
raceincome		Black, Non-Hispanic, < PL	Hispanic, < PL	0.006
raceincome		Black, Non-Hispanic, < PL	Other, < PL	0.423
raceincome		Black, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	< 0.0005
raceincome		Black, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.075
raceincome		Black, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	< 0.0005
raceincome		Black, Non-Hispanic, < PL	Hispanic, >= PL	< 0.0005
raceincome		Black, Non-Hispanic, < PL	Other, >= PL	0.312
raceincome		Asian, Non-Hispanic, < PL	Hispanic, < PL	0.027
raceincome		Asian, Non-Hispanic, < PL	Other, < PL	0.027
raceincome		Asian, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.074
raceincome		Asian, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.010
raceincome		Asian, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.172
raceincome		Asian, Non-Hispanic, < PL	Hispanic, >= PL	0.095
raceincome		Asian, Non-Hispanic, < PL	Other, >= PL	0.010
raceincome		Hispanic, < PL	Other, < PL	0.606
raceincome		Hispanic, < PL	White, Non-Hispanic, >= PL	0.042
raceincome		Hispanic, < PL	Black, Non-Hispanic, >= PL	0.218
raceincome		Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.044
raceincome		Hispanic, < PL	Hispanic, >= PL	0.033
raceincome		Hispanic, < PL	Other, >= PL	0.225
raceincome		Other, < PL	White, Non-Hispanic, >= PL	0.202
raceincome		Other, < PL	Black, Non-Hispanic, >= PL	1.000
raceincome		Other, < PL	Asian, Non-Hispanic, >= PL	0.105
raceincome		Other, < PL	Hispanic, >= PL	0.155
raceincome		Other, < PL	Other, >= PL	0.836
raceincome		White, Non-Hispanic, >= PL	Black, Non-Hispanic, >= PL	< 0.0005

AGAINST	ADJUST	RACEINC1	RACEINC2	PVAL
raceincome		White, Non-Hispanic, >= PL	Asian, Non-Hispanic, >= PL	0.338
raceincome		White, Non-Hispanic, >= PL	Hispanic, >= PL	0.584
raceincome		White, Non-Hispanic, >= PL	Other, >= PL	0.005
raceincome		Black, Non-Hispanic, >= PL	Asian, Non-Hispanic, >= PL	0.003
raceincome		Black, Non-Hispanic, >= PL	Hispanic, >= PL	< 0.0005
raceincome		Black, Non-Hispanic, >= PL	Other, >= PL	0.712
raceincome		Asian, Non-Hispanic, >= PL	Hispanic, >= PL	0.525
raceincome		Asian, Non-Hispanic, >= PL	Other, >= PL	0.009
raceincome		Hispanic, >= PL	Other, >= PL	0.006
raceincome	age gender	White, Non-Hispanic, < PL	Black, Non-Hispanic, < PL	0.004
raceincome	age gender	White, Non-Hispanic, < PL	Asian, Non-Hispanic, < PL	0.036
raceincome	age gender	White, Non-Hispanic, < PL	Hispanic, < PL	0.649
raceincome	age gender	White, Non-Hispanic, < PL	Other, < PL	0.504
raceincome	age gender	White, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.208
raceincome	age gender	White, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.142
raceincome	age gender	White, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.117
raceincome	age gender	White, Non-Hispanic, < PL	Hispanic, >= PL	0.156
raceincome	age gender	White, Non-Hispanic, < PL	Other, >= PL	0.156
raceincome	age gender	Black, Non-Hispanic, < PL	Asian, Non-Hispanic, < PL	0.002
raceincome	age gender	Black, Non-Hispanic, < PL	Hispanic, < PL	0.007
raceincome	age gender	Black, Non-Hispanic, < PL	Other, < PL	0.415
raceincome	age gender	Black, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.071
raceincome	age gender	Black, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Hispanic, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Other, >= PL	0.318
raceincome	age gender	Asian, Non-Hispanic, < PL	Hispanic, < PL	0.025
raceincome	age gender	Asian, Non-Hispanic, < PL	Other, < PL	0.029
raceincome	age gender	Asian, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.076
raceincome	age gender	Asian, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.010
raceincome	age gender	Asian, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.171
raceincome	age gender	Asian, Non-Hispanic, < PL	Hispanic, >= PL	0.096
raceincome	age gender	Asian, Non-Hispanic, < PL	Other, >= PL	0.010
raceincome	age gender	Hispanic, < PL	Other, < PL	0.650
raceincome	age gender	Hispanic, < PL	White, Non-Hispanic, >= PL	0.031
raceincome	age gender	Hispanic, < PL	Black, Non-Hispanic, >= PL	0.256
raceincome	age gender	Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.041
raceincome	age gender	Hispanic, < PL	Hispanic, >= PL	0.028
raceincome	age gender	Hispanic, < PL	Other, >= PL	0.242

AGAINST	ADJUST	RACEINC1	RACEINC2	PVAL
raceincome	age gender	Other, < PL	White, Non-Hispanic, >= PL	0.214
raceincome	age gender	Other, < PL	Black, Non-Hispanic, >= PL	0.986
raceincome	age gender	Other, < PL	Asian, Non-Hispanic, >= PL	0.118
raceincome	age gender	Other, < PL	Hispanic, >= PL	0.171
raceincome	age gender	Other, < PL	Other, >= PL	0.815
raceincome	age gender	White, Non-Hispanic, >= PL	Black, Non-Hispanic, >= PL	< 0.0005
raceincome	age gender	White, Non-Hispanic, >= PL	Asian, Non-Hispanic, >= PL	0.359
raceincome	age gender	White, Non-Hispanic, >= PL	Hispanic, >= PL	0.631
raceincome	age gender	White, Non-Hispanic, >= PL	Other, >= PL	0.005
raceincome	age gender	Black, Non-Hispanic, >= PL	Asian, Non-Hispanic, >= PL	0.003
raceincome	age gender	Black, Non-Hispanic, >= PL	Hispanic, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, >= PL	Other, >= PL	0.696
raceincome	age gender	Asian, Non-Hispanic, >= PL	Hispanic, >= PL	0.530
raceincome	age gender	Asian, Non-Hispanic, >= PL	Other, >= PL	0.009
raceincome	age gender	Hispanic, >= PL	Other, >= PL	0.006

The race and income comparisons shown in Tables 5 and 6 are of particular interest for ACE. It is useful to display those same results so that for each race/ethnicity pair or race/ethnicity/income pair, the p-values for the different approaches can be easily compared. In Table 7, the p-values for each race/ethnicity pair are shown for the overall comparison (from Table 5), for the comparison when both groups are below the poverty level (from Table 6), and for the comparison when both groups are at or above the poverty level (also from Table 6). Table 8 summarizes the race/ethnicity/income comparisons when one race/ethnicity group is below the poverty level and the other race/ethnicity group is at or above the poverty level. The p-values for the unadjusted and adjusted analyses are shown. These tables confirm the general finding of significantly lower asthma prevalence for Non-Hispanic Blacks, especially for those below the poverty level.

Table 7. Statistical significance tests comparing the proportions of children ever diagnosed with asthma and having an asthma attack in the last 12 months, between pairs of race/ethnicity groups, for 2005-2008.

		P-VALUES					
RACE1	**RACE2**	**All incomes**	**All incomes (adjusted for age, gender, income)**	**Below Poverty Level**	**Below Poverty Level (adjusted for age, gender)**	**At or Above Poverty Level**	**At or Above Poverty Level (adjusted for age, gender)**
White, Non-Hispanic	Black, Non-Hispanic	< 0.0005	< 0.0005	0.004	0.004	< 0.0005	< 0.0005
White, Non-Hispanic	Asian, Non-Hispanic	0.139	0.144	0.037	0.036	0.338	0.359
White, Non-Hispanic	Hispanic	0.630	0.937	0.649	0.649	0.584	0.631

		P-VALUES					
RACE1	**RACE2**	**All incomes**	**All incomes (adjusted for age, gender, income)**	**Below Poverty Level**	**Below Poverty Level (adjusted for age, gender)**	**At or Above Poverty Level**	**At or Above Poverty Level (adjusted for age, gender)**
White, Non-Hispanic	Other	0.005	0.009	0.465	0.504	0.005	0.005
Black, Non-Hispanic	Asian, Non-Hispanic	< 0.0005	< 0.0005	0.002	0.002	0.003	0.003
Black, Non-Hispanic	Hispanic	< 0.0005	< 0.0005	0.006	0.007	< 0.0005	< 0.0005
Black, Non-Hispanic	Other	0.777	0.917	0.423	0.415	0.712	0.696
Asian, Non-Hispanic	Hispanic	0.108	0.178	0.027	0.025	0.525	0.530
Asian, Non-Hispanic	Other	0.003	0.004	0.027	0.029	0.009	0.009
Hispanic	Other	0.014	0.012	0.606	0.650	0.006	0.006

Table 8. Statistical significance tests comparing the proportions of children ever diagnosed with asthma and having an asthma attack in the last 12 months, between pairs of race/ethnicity/income groups at different income levels, for 2005-2008.

		P-VALUES	
RACEINC1	**RACEINC2**	**Unadjusted**	**Adjusted (for age, gender)**
White, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.246	0.208
White, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.119	0.142
White, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.125	0.117
White, Non-Hispanic, < PL	Hispanic, >= PL	0.172	0.156
White, Non-Hispanic, < PL	Other, >= PL	0.144	0.156
Black, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	< 0.0005	< 0.0005
Black, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.075	0.071
Black, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	< 0.0005	< 0.0005
Black, Non-Hispanic, < PL	Hispanic, >= PL	< 0.0005	< 0.0005
Black, Non-Hispanic, < PL	Other, >= PL	0.312	0.318
Asian, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.074	0.076
Asian, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.010	0.010
Asian, Non-Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.172	0.171
Asian, Non-Hispanic, < PL	Hispanic, >= PL	0.095	0.096
Asian, Non-Hispanic, < PL	Other, >= PL	0.010	0.010
Hispanic, < PL	White, Non-Hispanic, >= PL	0.042	0.031
Hispanic, < PL	Black, Non-Hispanic, >= PL	0.218	0.256
Hispanic, < PL	Asian, Non-Hispanic, >= PL	0.044	0.041
Hispanic, < PL	Hispanic, >= PL	0.033	0.028
Hispanic, < PL	Other, >= PL	0.225	0.242
Other, < PL	White, Non-Hispanic, >= PL	0.202	0.214

		P-VALUES	
RACEINC1	**RACEINC2**	**Unadjusted**	**Adjusted (for age, gender)**
Other, < PL	Black, Non-Hispanic, >= PL	1.000	0.986
Other, < PL	Asian, Non-Hispanic, >= PL	0.105	0.118
Other, < PL	Hispanic, >= PL	0.155	0.171
Other, < PL	Other, >= PL	0.836	0.815

NHANES Measures – Trend Estimation and Year-to-Year Changes

Trend Estimation

The proposed statistical methods for analyzing the NHANES data use a similar approach to the NHIS logistic regression analyses. Each of the NHIS logistic regression analyses of the prevalence is replaced by a weighted linear regression analysis of the percentile value. For NHANES the statistical comparisons use the percentile values and their standard errors. The weight is the reciprocal of the estimated variance. For the trend analyses, the NHIS year becomes the middle year of the NHANES period. This is necessary because the NHANES data were not collected continuously until 1999-2000, and the NHANES data are currently collected over a two-year period. Thus the reported NHANES trend results estimate annual changes rather than the changes between NHANES periods.

We will illustrate the proposed approach using the median blood lead for children ages 1 to 5 and the NHANES data for the following periods. The same methods would work as future periods of data are added and would also work for the 95th percentile or any other selected percentile.

- NHANES III Phase 1: October 1988 to October 1991. Middle year: 1990.3
- NHANES III Phase 2: September 1991 to October 1994. Middle year: 1993.3
- NHANES 1999-2000: Middle year = 1999.5
- NHANES 2001-2002: Middle year = 2001.5
- NHANES 2003-2004: Middle year = 2003.5
- NHANES 2005-2006: Middle year = 2005.5
- NHANES 2007-2008: Middle year = 2007.5

Unadjusted Test for Trend

Table 9 shows the medians of the blood lead for children ages 1 to 5, by NHANES period and their standard errors. These medians and standard errors were computed using SUDAAN and SAS software and the method described in the Appendix "NHANES Percentile Relative Standard Error Calculations." For consistency, the medians are given by the P_{CDC} values defined in the Appendix.[9] This method is a version of a method proposed by CDC that is based

[9] The median of a sample can have different values depending upon the algorithm used. The SAS and SUDAAN software packages use different algorithms to compute percentiles from survey data. The Korn and Graubard method P_{CDC} value gives yet another estimate of a median, which is often, but not always, equal to the SAS estimate. In most cases these three estimates are quite close, exceptions being for small samples or when there are several tied values close to the median. Since the Korn and Graubard method is used for the standard errors analyzed here, it is also appropriate to use that approach for the medians themselves.

on the Clopper-Pearson binomial confidence intervals adapted for complex surveys by Korn and Graubard (see Korn and Graubard, 1999[10], p. 65).

Table 9. Median of blood lead (µg/dL) and percentage above overall median for children ages 1 to 5, by NHANES period, 1988-2008

Period	**Median**	**Standard Error of Median**
NHANES III Phase 1 (1988-1991)	3.4	0.17
NHANES III Phase 2 (1991-1994)	2.5	0.12
NHANES 1999-2000	2.2	0.14
NHANES 2001-2002	1.6	0.07
NHANES 2003-2004	1.7	0.07
NHANES 2005-2006	1.43	0.05
NHANES 2007-2008	1.43	0.07

The percentiles are assumed to have been generated from the statistical model:

$$\text{Median (year)} = \text{Intercept} + \text{Trend} \times \text{Year} + \text{Error}.$$

In this equation, “Year” is assumed to be a numerical variable rather than a categorical variable and the observed values are the middle years of each NHANES period. The error terms (observed statistic minus expected statistic) are assumed to be independent and normally distributed with a mean of zero and a known variance, v(y), that depends upon the year. The independence holds for NHANES III Phases 1 and 2 combined (1988-1994) and the continuous NHANES surveys from 1999 to 2008 because the NHANES survey samples were independently selected for each survey period, treating NHANES III as a single survey.[11] However, the two NHANES III Phases are not statistically independent since the two phases used the same strata. Since we are interested in comparing values for the two NHANES III phases, the analysis makes the approximation that the data from these two phases are independent; the likely impact of this approximation is that the statistical significance of the trend will be overstated. The normality holds approximately because of the central limit theorem. The variance v(y) is the variance of the blood lead median for year y, calculated as the square of the standard error. For this method, we ignore the fact that v(y) is estimated from survey data and so v(y), itself, is uncertain.[12]

The Intercept and Trend are estimated using weighted linear regression. The “weight” for year y is the reciprocal of the variance v(y).[13] To implement this calculation in SAS, the SAS procedure

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[10] Korn E. L., Graubard B. I. 1999. *Analysis of Health Surveys.* Wiley.

[11] There may be some statistical dependence between the blood lead population distributions in different survey periods, but for these analyses we are only considering the sampling variability due to the survey design.

[12] One reviewer proposed using a bootstrap approach to account for the uncertainty of v(y). Although it is possible to adapt the bootstrap approach to survey data, it would appear to be too computer-intensive for routine application to the ACE NHANES indicators, because the Korn and Graubard method of calculating standard errors is itself computer-intensive.

[13] The statistical model for year y is of the form:
Median (y) = Intercept + Trend $\times$ y + Error, where Error is normally distributed, mean zero, variance v(y).
This model is mathematically equivalent to:
Median (y)/$\sqrt{v(y)}$ = Intercept/$\sqrt{v(y)}$ + Trend $\times$ y /$\sqrt{v(y)}$ + Error2, where Error2 is normally distributed, mean zero, variance 1.
If we define the weight w(y) = 1/v(y), then the sum of squares of Error2 is given by:
$\Sigma\{\text{Median (y)}/\sqrt{v(y)} - \text{Intercept}/\sqrt{v(y)} - \text{Trend} \times y/\sqrt{v(y)}\}^2 =$
$\Sigma w(y) \times \{\text{Median (y)} - \text{Intercept} - \text{Trend} \times y)\}^2$.

GENMOD was used to regress the annual statistic against the year. The WEIGHT variable was set to equal the reciprocal of v(y). The option NOSCALE for the MODEL statement was applied, because the variance for year y is given by v(y) itself and not some unknown multiple of v(y) that needs to be estimated.

The estimated value of Trend is the predicted annual change in the median from one year to the following year, which is one half of the predicted change between two consecutive two-year NHANES periods. If the estimated value of Trend is statistically significantly different from zero at the five percent level, then a statistically significant trend has been found.

In this method, the survey design is taken into account, since the survey design is used to compute the annual percentile and its estimated variance. The method assumes that the estimated percentile values are normally distributed (which holds, approximately), and ignores the uncertainty in the estimated variances. The method also assumes that the percentiles for different NHANES periods are statistically independent, which is approximately valid because the NHANES survey design selected independent samples for different NHANES periods, with the exception that the samples for the two phases of NHANES III were not independently selected.

Adjusted Test for Trend

In a similar manner to the NHIS adjusted test for trend, we also have selected an adjusted test for trend for the NHANES data. This is a test for trend adjusted for possible confounding effects of the demographic variables.

The adjusted analysis is restricted to the following model formulation:

$$\text{Median (year, age group, gender, race/ethnicity, income)} = \text{Intercept} + \text{Trend} \times \text{Year} + \text{f(age group)} + \text{g(gender)} + \text{h(race/ethnicity)} + \text{k(income)} + \text{Error.}$$

In this equation, “Year” is assumed to be a numerical variable rather than a categorical variable and the observed values are the middle years of each NHANES period. The functions f, g, h and k define the categorical variables for age group, gender, race/ethnicity, and income, represented by linear combinations of dummy variables. This model assumes there are no interactions between these four demographic effects. The error terms (observed statistic minus expected statistic) are assumed to be independent and normally distributed with a mean of zero and a known variance, v(y, a, g, r, i), that depends upon the year y, age group a, gender g, race/ethnicity r, and income i. The variance v(y, a, g, r, i) is the variance of the blood lead median for year y and the given demographic group combination, calculated as the square of the standard error. For this method, we ignore the fact that v(y, a , g, r, i) is estimated from survey data and so v(y, a, g, r, i), itself, is uncertain. The p-value for Trend tests for a trend adjusted for the demographic variables.

Unlike the unadjusted test for trend, the simplifying assumption that these medians are independent does not follow from the survey design, even if the two NHANES III phases are re-combined. In fact, for each year, the medians for different combinations of age group, gender, race/ethnicity, and year are not independent, because they are selected from the same strata and primary sampling units. The correlations between the medians for the same year but different demographic group combinations can be expected to cause the significance levels for the Trend to be overstated, so that the estimated p-values are lower than the true p-values. As a

By definition, weighted linear regression chooses the regression parameters to minimize this weighted sum of squares.

very rough approximation, the true p-values could be up to 0.01 or 0.02 higher than the estimated p-values. Accounting for these correlations using the Korn and Graubard approach would be analytically difficult and computer-intensive. This same issue applies to many of the NHANES analyses presented in this memorandum.

For analyses of blood lead medians in children ages 1 to 5, we propose the following categories:

Age groups

- 1 year
- 2 years
- 3 years
- 4 years
- 5 years

Gender groups

- Males
- Females

Race/ethnicity groups

- White, Non-Hispanic
- Black, Non-Hispanic
- Mexican-American
- Other

Income groups

- Below Poverty Level
- At or Above Poverty Level
- Unknown Income

The race/ethnicity groups are based on the RIDRETH1 NHANES variable and are the same as the groups used in the current ACE. The "Other" category includes Non-Hispanic Asian; Non-Hispanic Native American; Hispanic other than Mexican-American; those reporting multi-racial; and those with a missing value for race/ethnicity.

For income, there were a significant proportion of the respondents that did not report their family income and, unlike NHIS, imputed income is not available (other than for NHANES III). We therefore include the Unknown Income category as one of the income groups, since grouping the unknown income cases with one of the other groups would lead to unrealistic models for the effects of income.

A statistically significant adjusted trend would show that the blood lead median trend is statistically significant after adjusting for possible confounding effects of age, gender, race/ethnicity, and income.

<u>Stratified Tests for Trend</u>

To investigate possible interactions between the trend and the demographic group, we propose a stratified analysis that separately tests for a trend in each demographic group. The proposed analysis adjusts for possible confounding by the other demographic groups.

The following regression models are proposed, one for each demographic subset:

Adjusted trend test by age group

Median (year, age group, gender, race/ethnicity, income) =
Intercept + Trend × Year + g(gender) + h(race/ethnicity) + k(income) + Error
(model fitted to children in age group a only)

Adjusted trend test by gender

Median (year, age group, gender, race/ethnicity, income) =
Intercept + Trend × Year + f(age) + h(race/ethnicity) + k(income) + Error
(model fitted to children in gender group g only)

Adjusted trend test by race/ethnicity

Median (year, age group, gender, race/ethnicity, income) =
Intercept + Trend × Year + f(age) + g(gender) + k(income) = Error
(model fitted to children in race/ethnicity group r only)

Adjusted trend test by income

Median (year, age group, gender, race/ethnicity, income) =
Intercept + Trend × Year + f(age) + g(gender) + h(race/ethnicity) = Error
(model fitted to children in income group i only)

A statistically significant adjusted trend would show that the blood lead median trend in the particular demographic group is statistically significant after adjusting for the effects of the other demographic groups.

Year-to-Year Change

To compare NHANES medians in different NHANES periods, the set of trend analyses are repeated using only the data for the two periods of interest. For consistency, the year effect is again assumed to be numerical, so that the estimated Trend is the estimated annual change in the median. To estimate the period-to-period change for two consecutive two-year periods, the estimated Trend coefficient should be doubled; the p-value is not affected.

Results for Trends and Year-to-Year Changes in Blood Lead Medians

These weighted regression tests were applied to the blood lead data from NHANES. The trend test was first applied to the trend over the period 1988 to 2008 and then was applied to the trend over the period 1999 and later, in order to evaluate the more current trend. The year-to-year change test was applied to the change from 2005-2006 to 2007-2008. The results are shown in Tables 10 and 11, which have almost the same formats as Tables 2 and 3, respectively. The medians are shown in the QTILE column of Table 10. In Table 11, the “AGAINST” regression variable is denoted as “yearnum,” to emphasize that the year value is the numerical value of the middle of the NHANES period, shown in the VALUE column.

The results show that overall, and for each demographic group except for Other race/ethnicities, the trends in blood lead medians are very statistically significant, both for the entire period 1988 to 2008 and for the more recent trend from 1999 to 2008. Many of the p-values reported as < 0.0005 in Table 11 were in fact extremely small, sometimes below 10^{-100}, particularly for the trend analyses. These very low p-values overstate the significance because they ignore important uncertainties such as those due to the laboratory and reporting precision, the assumed regression model formulations, including the normality and independence assumptions, and the uncertainties in the standard errors of the percentiles. Thus a more realistic approach simply reports these values as below 0.0005, as shown. The change from 2005-2006 to 2007-2008 was zero overall for the unadjusted analysis but there was a very statistically significant increase after adjusting for age, gender, race, and income. The adjusted analyses show statistically significant increases for 1 year olds, females, those below the poverty level, and those with unknown income, and a statistically significant decrease for 4 year olds. One unexpected finding is that the 1999-2008 trend was highly significant for males, but negligible for females, after adjusting for age, race/ethnicity, and income.

Some of the statistical significance results for the 2005-2006 to 2007-2008 comparison shown in Table 11 may appear inconsistent when the percentiles in Table 10 are examined in detail. For example, the overall median is the same for both periods and yet the median decreased for Black, non-Hispanic and for Other race/ethnicity, and increased very slightly for the remaining two race/ethnicity groups. This result is an example of Simpson's paradox that can show inconsistent patterns for the median or another summary statistic when examined overall instead of for each stratum separately. This apparent inconsistency is because the trend in the median does not apply to the entire distribution. The resolution of these paradoxical results is either to examine results for the demographic subgroups or to use a statistical regression approach to adjust for demographic differences. The adjusted analysis shows a highly significant increase. A similar example shows a small decrease for the medians among those below the poverty level while the adjusted model shows a statistically significant increase. However, the statistical model used for the adjustments is also subject to uncertainty, since, for example, it includes the approximation that the year, age, gender, race, and income effects do not interact.

Table 10. Median of blood lead in children ages 1 to 5, by period and demographic group, for 1988-2008.

PERCENTILE	TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	QTILE
50	trend	1988	2008	yearnum		1990.3	3.40
50	trend	1988	2008	yearnum		1993.3	2.50
50	trend	1988	2008	yearnum		1999.5	2.20
50	trend	1988	2008	yearnum		2001.5	1.60
50	trend	1988	2008	yearnum		2003.5	1.70
50	trend	1988	2008	yearnum		2005.5	1.43
50	trend	1988	2008	yearnum		2007.5	1.43
50	trend	1988	2008	yearnum	1 year	1990.3	3.80
50	trend	1988	2008	yearnum	1 year	1993.3	3.30
50	trend	1988	2008	yearnum	1 year	1999.5	2.50
50	trend	1988	2008	yearnum	1 year	2001.5	1.90
50	trend	1988	2008	yearnum	1 year	2003.5	2.00
50	trend	1988	2008	yearnum	1 year	2005.5	1.58

PERCENTILE	TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	QTILE
50	trend	1988	2008	yearnum	1 year	2007.5	1.80
50	trend	1988	2008	yearnum	2 years	1990.3	3.80
50	trend	1988	2008	yearnum	2 years	1993.3	2.80
50	trend	1988	2008	yearnum	2 years	1999.5	2.30
50	trend	1988	2008	yearnum	2 years	2001.5	1.80
50	trend	1988	2008	yearnum	2 years	2003.5	1.80
50	trend	1988	2008	yearnum	2 years	2005.5	1.73
50	trend	1988	2008	yearnum	2 years	2007.5	1.68
50	trend	1988	2008	yearnum	3 years	1990.3	3.70
50	trend	1988	2008	yearnum	3 years	1993.3	2.40
50	trend	1988	2008	yearnum	3 years	1999.5	2.20
50	trend	1988	2008	yearnum	3 years	2001.5	1.60
50	trend	1988	2008	yearnum	3 years	2003.5	1.70
50	trend	1988	2008	yearnum	3 years	2005.5	1.23
50	trend	1988	2008	yearnum	3 years	2007.5	1.44
50	trend	1988	2008	yearnum	4 years	1990.3	3.20
50	trend	1988	2008	yearnum	4 years	1993.3	2.50
50	trend	1988	2008	yearnum	4 years	1999.5	1.70
50	trend	1988	2008	yearnum	4 years	2001.5	1.40
50	trend	1988	2008	yearnum	4 years	2003.5	1.50
50	trend	1988	2008	yearnum	4 years	2005.5	1.39
50	trend	1988	2008	yearnum	4 years	2007.5	1.24
50	trend	1988	2008	yearnum	5 years	1990.3	3.10
50	trend	1988	2008	yearnum	5 years	1993.3	2.15
50	trend	1988	2008	yearnum	5 years	1999.5	2.00
50	trend	1988	2008	yearnum	5 years	2001.5	1.35
50	trend	1988	2008	yearnum	5 years	2003.5	1.30
50	trend	1988	2008	yearnum	5 years	2005.5	1.27
50	trend	1988	2008	yearnum	5 years	2007.5	1.16
50	trend	1988	2008	yearnum	Males	1990.3	3.50
50	trend	1988	2008	yearnum	Males	1993.3	2.80
50	trend	1988	2008	yearnum	Males	1999.5	2.10
50	trend	1988	2008	yearnum	Males	2001.5	1.70
50	trend	1988	2008	yearnum	Males	2003.5	1.60
50	trend	1988	2008	yearnum	Males	2005.5	1.40
50	trend	1988	2008	yearnum	Males	2007.5	1.43
50	trend	1988	2008	yearnum	Females	1990.3	3.60
50	trend	1988	2008	yearnum	Females	1993.3	2.40
50	trend	1988	2008	yearnum	Females	1999.5	2.10
50	trend	1988	2008	yearnum	Females	2001.5	1.60
50	trend	1988	2008	yearnum	Females	2003.5	1.50
50	trend	1988	2008	yearnum	Females	2005.5	1.46
50	trend	1988	2008	yearnum	Females	2007.5	1.41
50	trend	1988	2008	yearnum	White, Non-Hispanic	1990.3	3.00
50	trend	1988	2008	yearnum	White, Non-Hispanic	1993.3	2.30
50	trend	1988	2008	yearnum	White, Non-Hispanic	1999.5	2.10
50	trend	1988	2008	yearnum	White, Non-Hispanic	2001.5	1.50
50	trend	1988	2008	yearnum	White, Non-Hispanic	2003.5	1.40

PERCENTILE	TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	QTILE
50	trend	1988	2008	yearnum	White, Non-Hispanic	2005.5	1.34
50	trend	1988	2008	yearnum	White, Non-Hispanic	2007.5	1.35
50	trend	1988	2008	yearnum	Black, Non-Hispanic	1990.3	5.20
50	trend	1988	2008	yearnum	Black, Non-Hispanic	1993.3	4.30
50	trend	1988	2008	yearnum	Black, Non-Hispanic	1999.5	2.75
50	trend	1988	2008	yearnum	Black, Non-Hispanic	2001.5	2.40
50	trend	1988	2008	yearnum	Black, Non-Hispanic	2003.5	2.50
50	trend	1988	2008	yearnum	Black, Non-Hispanic	2005.5	2.01
50	trend	1988	2008	yearnum	Black, Non-Hispanic	2007.5	1.68
50	trend	1988	2008	yearnum	Mexican-American	1990.3	3.80
50	trend	1988	2008	yearnum	Mexican-American	1993.3	3.00
50	trend	1988	2008	yearnum	Mexican-American	1999.5	2.00
50	trend	1988	2008	yearnum	Mexican-American	2001.5	1.60
50	trend	1988	2008	yearnum	Mexican-American	2003.5	1.60
50	trend	1988	2008	yearnum	Mexican-American	2005.5	1.38
50	trend	1988	2008	yearnum	Mexican-American	2007.5	1.40
50	trend	1988	2008	yearnum	Other	1990.3	3.70
50	trend	1988	2008	yearnum	Other	1993.3	2.50
50	trend	1988	2008	yearnum	Other	1999.5	1.80
50	trend	1988	2008	yearnum	Other	2001.5	1.50
50	trend	1988	2008	yearnum	Other	2003.5	1.80
50	trend	1988	2008	yearnum	Other	2005.5	1.63
50	trend	1988	2008	yearnum	Other	2007.5	1.34
50	trend	1988	2008	yearnum	Below Poverty Level	1990.3	4.70
50	trend	1988	2008	yearnum	Below Poverty Level	1993.3	4.00
50	trend	1988	2008	yearnum	Below Poverty Level	1999.5	2.85
50	trend	1988	2008	yearnum	Below Poverty Level	2001.5	2.30
50	trend	1988	2008	yearnum	Below Poverty Level	2003.5	2.20
50	trend	1988	2008	yearnum	Below Poverty Level	2005.5	1.74
50	trend	1988	2008	yearnum	Below Poverty Level	2007.5	1.70
50	trend	1988	2008	yearnum	At or Above Poverty Level	1990.3	3.00
50	trend	1988	2008	yearnum	At or Above Poverty Level	1993.3	2.15
50	trend	1988	2008	yearnum	At or Above Poverty Level	1999.5	1.80
50	trend	1988	2008	yearnum	At or Above Poverty Level	2001.5	1.30
50	trend	1988	2008	yearnum	At or Above Poverty Level	2003.5	1.30
50	trend	1988	2008	yearnum	At or Above Poverty Level	2005.5	1.33
50	trend	1988	2008	yearnum	At or Above Poverty Level	2007.5	1.30
50	trend	1988	2008	yearnum	Unknown Income	1990.3	3.40
50	trend	1988	2008	yearnum	Unknown Income	1993.3	3.70
50	trend	1988	2008	yearnum	Unknown Income	1999.5	2.60
50	trend	1988	2008	yearnum	Unknown Income	2001.5	1.80
50	trend	1988	2008	yearnum	Unknown Income	2003.5	1.70
50	trend	1988	2008	yearnum	Unknown Income	2005.5	1.94
50	trend	1988	2008	yearnum	Unknown Income	2007.5	1.57

Table 11. Statistical significance tests comparing the trends and year-to-year changes in the medians of blood lead in children ages 1 to 5, for 1988-2008.

TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	ADJUST	BETA	PVAL

TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	ADJUST	BETA	PVAL
trend	1988	2008	yearnum			-0.09383	< 0.0005
trend	1988	2008	yearnum		age gender race income	-0.07669	< 0.0005
trend	1988	2008	yearnum	1 year	gender race income	-0.06822	< 0.0005
trend	1988	2008	yearnum	2 years	gender race income	-0.13157	< 0.0005
trend	1988	2008	yearnum	3 years	gender race income	-0.06090	< 0.0005
trend	1988	2008	yearnum	4 years	gender race income	-0.08946	< 0.0005
trend	1988	2008	yearnum	5 years	gender race income	-0.08930	< 0.0005
trend	1988	2008	yearnum	Males	age race income	-0.11077	< 0.0005
trend	1988	2008	yearnum	Females	age race income	-0.06794	< 0.0005
trend	1988	2008	yearnum	White, Non-Hispanic	age gender income	-0.12167	< 0.0005
trend	1988	2008	yearnum	Black, Non-Hispanic	age gender income	-0.15525	< 0.0005
trend	1988	2008	yearnum	Mexican-American	age gender income	-0.11569	< 0.0005
trend	1988	2008	yearnum	Other	age gender income	0.00089	0.858
trend	1988	2008	yearnum	Below Poverty Level	age gender race	-0.14308	< 0.0005
trend	1988	2008	yearnum	At or Above Poverty Level	age gender race	-0.05336	< 0.0005
trend	1988	2008	yearnum	Unknown Income	age gender race	-0.19007	< 0.0005
trend	1999	2008	yearnum			-0.06323	< 0.0005
trend	1999	2008	yearnum		age gender race income	-0.02731	< 0.0005
trend	1999	2008	yearnum	1 year	gender race income	-0.02494	0.002
trend	1999	2008	yearnum	2 years	gender race income	-0.11403	< 0.0005
trend	1999	2008	yearnum	3 years	gender race income	0.03566	< 0.0005
trend	1999	2008	yearnum	4 years	gender race income	0.02923	0.001
trend	1999	2008	yearnum	5 years	gender race income	-0.05619	< 0.0005
trend	1999	2008	yearnum	Males	age race income	-0.05320	< 0.0005
trend	1999	2008	yearnum	Females	age race income	-0.00024	0.960
trend	1999	2008	yearnum	White, Non-Hispanic	age gender income	-0.05811	< 0.0005
trend	1999	2008	yearnum	Black, Non-Hispanic	age gender income	-0.13081	< 0.0005
trend	1999	2008	yearnum	Mexican-American	age gender income	-0.05734	< 0.0005
trend	1999	2008	yearnum	Other	age gender income	0.03345	< 0.0005
trend	1999	2008	yearnum	Below Poverty Level	age gender race	-0.07092	< 0.0005
trend	1999	2008	yearnum	At or Above Poverty Level	age gender race	0.01368	0.004
trend	1999	2008	yearnum	Unknown Income	age gender race	0.16500	0.053
year-to-year	2005	2008	yearnum			0.00000	1.000
year-to-year	2005	2008	yearnum		age gender race income	0.14387	< 0.0005
year-to-year	2005	2008	yearnum	1 year	gender race income	0.33486	< 0.0005
year-to-year	2005	2008	yearnum	2 years	gender race income	0.01558	0.696
year-to-year	2005	2008	yearnum	3 years	gender race income	0.05190	0.121
year-to-year	2005	2008	yearnum	4 years	gender race income	-0.10465	0.009
year-to-year	2005	2008	yearnum	5 years	gender race income	-0.05116	0.250
year-to-year	2005	2008	yearnum	Males	age race income	0.02212	0.345
year-to-year	2005	2008	yearnum	Females	age race income	0.05935	0.007
year-to-year	2005	2008	yearnum	White, Non-Hispanic	age gender income	-0.05905	0.111
year-to-year	2005	2008	yearnum	Black, Non-Hispanic	age gender income	-0.05335	0.245
year-to-	2005	2008	yearnum	Mexican-American	age gender income	0.04115	0.177

TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	ADJUST	BETA	PVAL
year							
year-to-year	2005	2008	yearnum	Other	age gender income	0.07804	0.042
year-to-year	2005	2008	yearnum	Below Poverty Level	age gender race	0.07351	0.015
year-to-year	2005	2008	yearnum	At or Above Poverty Level	age gender race	0.02286	0.229
year-to-year	2005	2008	yearnum	Unknown Income	age gender race	1.37500	< 0.0005

NHANES Measures – Compare Demographic Groups

To compare NHANES medians among different demographic groups an analogous approach to the NHIS analysis is applied. The analysis combines the data from multiple NHANES periods.[14] The same demographic group categories as the trend analyses are used. The blood lead medians for 2005-2008 for each demographic group are tabulated in Table 12, using a similar format to Table 2.

Table 12. Medians of blood lead in children ages 1 to 5, by demographic group, for 2005-2008.

PERCENTILE	TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	QTILE
50	demographic	2005	2008	age		1 year	1.67
50	demographic	2005	2008	age		2 years	1.70
50	demographic	2005	2008	age		3 years	1.34
50	demographic	2005	2008	age		4 years	1.30
50	demographic	2005	2008	age		5 years	1.24
50	demographic	2005	2008	gender		Males	1.39
50	demographic	2005	2008	gender		Females	1.43
50	demographic	2005	2008	race		White, Non-Hispanic	1.34
50	demographic	2005	2008	race		Black, Non-Hispanic	1.89
50	demographic	2005	2008	race		Mexican-American	1.39
50	demographic	2005	2008	race		Other	1.40
50	demographic	2005	2008	income		Below Poverty Level	1.73
50	demographic	2005	2008	income		At or Above Poverty Level	1.33
50	demographic	2005	2008	income		Unknown Income	1.68
50	demographic	2005	2008	income	White, Non-Hispanic	Below Poverty Level	1.44
50	demographic	2005	2008	income	White, Non-Hispanic	At or Above Poverty Level	1.29
50	demographic	2005	2008	income	White, Non-	Unknown Income	1.45

[14] The following note would apply to a demographic comparison that included data from both NHANES III and NHANES 1999-2000 later and thus does not apply to the example demographic comparisons for medians of blood lead over 2005 to 2008. The NHANES survey design selects independent random samples of subjects for each survey period, treating NHANES III 1988-1994 as a single survey period. For NHANES III, the strata over the entire six-year period were numbered from 1 to 49. For NHANES 1999-2000 and later, the strata were numbered from 1 to 14 in 1999-2000, 15 to 28 in 2001-2002, etc. To properly analyze the NHANES data, it is necessary to distinguish the strata in NHANES III from the same numbered strata in NHANES 1999-2000 and later. Otherwise, the statistical analysis would incorrectly treat all the data from the stratum numbered 1 as having being selected from the same statistical stratum, and similarly for the other stratum numbers, which would lead to incorrect estimates of the variances and p-values, although the annual statistics would not be affected. For this reason, 1,000 should be added to the original stratum numbers for the NHANES III survey; instead of 1,000, any number that avoids overlaps between the NHANES III stratum numbers and the stratum numbers for 1999-2000 and later can be chosen.

PERCENTILE	TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	VALUE	QTILE
					Hispanic		
50	demographic	2005	2008	income	Black, Non-Hispanic	Below Poverty Level	2.35
50	demographic	2005	2008	income	Black, Non-Hispanic	At or Above Poverty Level	1.56
50	demographic	2005	2008	income	Black, Non-Hispanic	Unknown Income	3.41
50	demographic	2005	2008	income	Mexican-American	Below Poverty Level	1.57
50	demographic	2005	2008	income	Mexican-American	At or Above Poverty Level	1.30
50	demographic	2005	2008	income	Mexican-American	Unknown Income	1.41
50	demographic	2005	2008	income	Other	Below Poverty Level	1.87
50	demographic	2005	2008	income	Other	At or Above Poverty Level	1.22
50	demographic	2005	2008	income	Other	Unknown Income	1.30

There is a wide variety of possible demographic comparisons that could be addressed using statistical tests. These statistical tests are intended to confirm or evaluate the patterns that we can see when comparing the percentiles for different race and family income combinations as well as for other demographic subgroups. The results of these statistical tests can then be used to decide which differences should be highlighted in our discussions of the various NHANES indicators. In this memorandum we present statistical methods for the comparisons that we expect to be of interest for most of the NHANES indicators, but in some cases it may be necessary to use similar statistical methods for comparisons not considered here.

The most important comparison is for differences among demographic groups. The unadjusted tests tabulated in Table 13 below use the models

Median (age group) = Intercept + f(age) + Error,
Median (gender group) = Intercept + g(gender) + Error,
Median (race/ethnicity group) = Intercept + h(race/ethnicity) + Error, or
Median (income group) = Intercept + k(income) + Error

The adjusted tests tabulated in Table 13 use the model

Median (age group, gender, race/ethnicity, income) = Intercept + f(age) + g(gender) + h(race/ethnicity) + k(income) + Error

Test for age: Test f(age) = 0.
Test for gender: Test g(gender) = 0.
Test for race/ethnicity: Test h(race/ethnicity) = 0.
Test for income: Test k(income) = 0.

Table 14 below tabulates contrast comparisons between pairs of race/ethnicity or race/ethnicity/income groups. These answer questions about whether two specific race/ethnicity or race/ethnicity/income groups are significantly different and can be used to evaluate or confirm statements that a particular race/ethnicity or race/ethnicity/income group has the highest median, i.e., that the differences are not attributable to random variation.

For example, consider the unadjusted test for race/ethnicity differences, based on the model

Median (race/ethnicity group) = Intercept + h(race/ethnicity) + Error

The overall test is for the hypothesis that there are no race/ethnicity differences. Number the four race/ethnicity groups from 1 to 4 and define the four associated dummy variables so that I_j

is the dummy variable that equals 1 for members of group j and equals 0 otherwise. Then the unadjusted weighted regression model for race is of the form:

$$\text{Median (race/ethnicity group)} = \text{Intercept} + h(1)I_1 + h(2)I_2 + h(3)I_3 + h(4)I_4 + h(5)I_5 + \text{Error}$$

To compare groups j and k, the appropriate statistical test is of the null hypothesis h(j) = h(k), which tests the null hypothesis that the two groups have the same regression parameters, and hence the same predicted median. This test is easily performed in the SAS GENMOD procedure using an effects contrast. For example, to compare groups 1 and 3, the contrast statement is coded as

```
contrast '1v3' race 1 0 −1 0 0;
```

A p-value is calculated for each pair of race/ethnicity groups. The same set of contrast comparisons are used for the adjusted model, with additional terms for age, gender, and income. As for the NHIS analyses, we choose not to make an adjustment for the multiple paired comparisons.

As mentioned above, we would like to use the results to evaluate statements about the race/ethnicity group with the highest percentile. For example, Table 12 shows that Non-Hispanic Black children had the highest blood lead median among the four race/ethnicity groups in 2005-2008. A statistical test for the specific alternative hypothesis that Non-Hispanic Black children had the highest median among the four race/ethnicity groups is not available. Instead we propose to examine the paired comparisons between the Black, Non-Hispanic group and each of the other three race/ethnicity groups and if we find that all the differences are statistically significant, then we can confirm that the Non-Hispanic Black children had the highest median among the four race/ethnicity groups since the differences are not attributable to random variation. As discussed in the last paragraph, we choose not to make an adjustment for the multiple comparisons.

Also of interest are evaluating differences between pairs of race/ethnicity/income groups and evaluating statements about the race/ethnicity/income group with the highest median. For example, Table 12 shows that Black, Non-Hispanic children below the poverty level had the highest median among all the race/ethnicity/income groups of interest, excluding the less interesting unknown income category. For these analyses, the unadjusted model was of the form:

$$\text{Median (race/ethnicity/income group)} = \text{Intercept} + q(\text{race/ethnicity and income}) + \text{Error}$$

The categorical variable q has 12 categories, including the four combinations of race/ethnicity with unknown income. For each of the other eight categories, we calculated the statistical significance of each of the 56 paired differences. This model allows for possible interactions between race/ethnicity and income. The results are tabulated in Table 14 below.

The NHANES demographic groups for income are “Below Poverty Level,” “At or Above Poverty Level,” and ‘Unknown Income.” The overall test for income is for the hypothesis of no differences among all three groups. Also of interest is a comparison between the two specific groups “Below Poverty Level” and “At or Above Poverty Level.” Although this comparison could be made using an effects contrast applied to the data from all three income groups, we chose a slightly different approach of testing for an income difference in the model using only those two groups with known income. Those comparisons are indicated by the subset “Known Income”

Both the two- and three-income group comparisons were tested without adjusting for other covariates and adjusting for age, gender, and race/ethnicity.

Results for NHANES Tests on Demographic Group Differences in Blood Lead Medians

The demographic comparisons presented in Table 13 show significant differences for age, race/ethnicity, and income, both unadjusted and adjusted. The differences in the blood lead medians between those below poverty level and at or above poverty are also significant.

Table 13. Statistical significance tests comparing the medians of blood lead in children ages 1 to 5 among demographic groups, for 2005-2008.

TYPE	FROMYEAR	TOYEAR	AGAINST	SUBSET	ADJUST	PVAL
demographic	2005	2008	age			< 0.0005
demographic	2005	2008	gender			0.630
demographic	2005	2008	race			0.001
demographic	2005	2008	income			< 0.0005
demographic	2005	2008	income	Known Income		< 0.0005
demographic	2005	2008	age		gender race income	< 0.0005
demographic	2005	2008	gender		age race income	0.410
demographic	2005	2008	race		age gender income	< 0.0005
demographic	2005	2008	income		age gender race	< 0.0005
demographic	2005	2008	income	Known Income	age gender race	< 0.0005

The paired race/ethnicity comparisons in Table 14 show statistically significant differences between White, Non-Hispanic and Black, Non-Hispanic, Black, Non-Hispanic and Mexican-American, and between Black, Non-Hispanic and Other. Also, the adjusted analyses show statistically significant differences between White, Non-Hispanic and Mexican-American. The results confirm that Black, Non-Hispanic children have the highest median blood lead (unadjusted and adjusted model). The adjusted model for raceincome shows that Black, Non-Hispanic children below the poverty level have the highest median blood lead among the race/ethnicity/income groups with known incomes.

Table 14. Statistical significance tests comparing the medians of blood lead in children ages 1 to 5, between pairs of race/ethnicity and race/ethnicity/income groups, for 2005-2008.

AGAINST	ADJUST	RACEINC1	RACEINC2	PVAL
race		White, Non-Hispanic	Black, Non-Hispanic	< 0.0005
race		White, Non-Hispanic	Mexican-American	0.469
race		White, Non-Hispanic	Other	0.660
race		Black, Non-Hispanic	Mexican-American	< 0.0005
race		Black, Non-Hispanic	Other	0.010
race		Mexican-American	Other	0.948
race	age gender income	White, Non-Hispanic	Black, Non-Hispanic	< 0.0005
race	age gender income	White, Non-Hispanic	Mexican-American	0.007
race	age gender income	White, Non-Hispanic	Other	0.204
race	age gender income	Black, Non-Hispanic	Mexican-American	< 0.0005
race	age gender income	Black, Non-Hispanic	Other	< 0.0005
race	age gender income	Mexican-American	Other	0.258
raceincome		White, Non-Hispanic, <	Black, Non-Hispanic, < PL	< 0.0005

AGAINST	ADJUST	RACEINC1	RACEINC2	PVAL
		PL		
raceincome		White, Non-Hispanic, < PL	Mexican-American, < PL	0.443
raceincome		White, Non-Hispanic, < PL	Other, < PL	0.104
raceincome		White, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.355
raceincome		White, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.522
raceincome		White, Non-Hispanic, < PL	Mexican-American, >= PL	0.412
raceincome		White, Non-Hispanic, < PL	Other, >= PL	0.270
raceincome		Black, Non-Hispanic, < PL	Mexican-American, < PL	< 0.0005
raceincome		Black, Non-Hispanic, < PL	Other, < PL	0.050
raceincome		Black, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	< 0.0005
raceincome		Black, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	< 0.0005
raceincome		Black, Non-Hispanic, < PL	Mexican-American, >= PL	< 0.0005
raceincome		Black, Non-Hispanic, < PL	Other, >= PL	< 0.0005
raceincome		Mexican-American, < PL	Other, < PL	0.183
raceincome		Mexican-American, < PL	White, Non-Hispanic, >= PL	0.001
raceincome		Mexican-American, < PL	Black, Non-Hispanic, >= PL	0.937
raceincome		Mexican-American, < PL	Mexican-American, >= PL	0.007
raceincome		Mexican-American, < PL	Other, >= PL	0.015
raceincome		Other, < PL	White, Non-Hispanic, >= PL	0.008
raceincome		Other, < PL	Black, Non-Hispanic, >= PL	0.195
raceincome		Other, < PL	Mexican-American, >= PL	0.012
raceincome		Other, < PL	Other, >= PL	0.009
raceincome		White, Non-Hispanic, >= PL	Black, Non-Hispanic, >= PL	0.021
raceincome		White, Non-Hispanic, >= PL	Mexican-American, >= PL	0.908
raceincome		White, Non-Hispanic, >= PL	Other, >= PL	0.604
raceincome		Black, Non-Hispanic, >= PL	Mexican-American, >= PL	0.042
raceincome		Black, Non-Hispanic, >= PL	Other, >= PL	0.039
raceincome		Mexican-American, >= PL	Other, >= PL	0.581
raceincome	age gender	White, Non-Hispanic, < PL	Black, Non-Hispanic, < PL	< 0.0005
raceincome	age gender	White, Non-Hispanic, < PL	Mexican-American, < PL	0.075
raceincome	age gender	White, Non-Hispanic, < PL	Other, < PL	0.372
raceincome	age gender	White, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.002
raceincome	age gender	White, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.704
raceincome	age gender	White, Non-Hispanic, < PL	Mexican-American, >= PL	< 0.0005
raceincome	age gender	White, Non-Hispanic, < PL	Other, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Mexican-American, < PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Other, < PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Mexican-American, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, < PL	Other, >= PL	< 0.0005
raceincome	age gender	Mexican-American, < PL	Other, < PL	0.567

AGAINST	ADJUST	RACEINC1	RACEINC2	PVAL
raceincome	age gender	Mexican-American, < PL	White, Non-Hispanic, >= PL	0.162
raceincome	age gender	Mexican-American, < PL	Black, Non-Hispanic, >= PL	0.126
raceincome	age gender	Mexican-American, < PL	Mexican-American, >= PL	0.010
raceincome	age gender	Mexican-American, < PL	Other, >= PL	0.013
raceincome	age gender	Other, < PL	White, Non-Hispanic, >= PL	0.126
raceincome	age gender	Other, < PL	Black, Non-Hispanic, >= PL	0.557
raceincome	age gender	Other, < PL	Mexican-American, >= PL	0.016
raceincome	age gender	Other, < PL	Other, >= PL	0.030
raceincome	age gender	White, Non-Hispanic, >= PL	Black, Non-Hispanic, >= PL	0.003
raceincome	age gender	White, Non-Hispanic, >= PL	Mexican-American, >= PL	0.115
raceincome	age gender	White, Non-Hispanic, >= PL	Other, >= PL	0.235
raceincome	age gender	Black, Non-Hispanic, >= PL	Mexican-American, >= PL	< 0.0005
raceincome	age gender	Black, Non-Hispanic, >= PL	Other, >= PL	< 0.0005
raceincome	age gender	Mexican-American, >= PL	Other, >= PL	0.773

The race and income comparisons shown in Tables 13 and 14 are of particular interest for ACE. It is useful to display those same results so that for each race/ethnicity pair or race/ethnicity/income pair, the p-values for the different approaches can be easily compared. In Table 15, the p-values for each race/ethnicity pair are shown for the overall comparison (from Table 13), for the comparison when both groups are below the poverty level (from Table 14), and for the comparison when both groups are at or above the poverty level (also from Table 14). Table 16 summarizes the race/ethnicity/income comparisons when one race/ethnicity group is below the poverty level and the other race/ethnicity group is at or above the poverty level. The p-values for the unadjusted and adjusted analyses are shown. These tables confirm the general finding of significantly higher median blood lead values for Non-Hispanic Blacks, especially for those below the poverty level.

Table 15. Statistical significance tests comparing the medians of blood lead in children ages 1 to 5, between pairs of race/ethnicity groups, for 2005-2008.

		P-VALUES					
RACE1	**RACE2**	**All incomes**	**All incomes (adjusted for age, gender, income)**	**Below Poverty Level**	**Below Poverty Level (adjusted for age, gender)**	**At or Above Poverty Level**	**At or Above Poverty Level (adjusted for age, gender)**
White, Non-Hispanic	Black, Non-Hispanic	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.021	0.003
White, Non-Hispanic	Mexican-American	0.469	0.007	0.443	0.075	0.908	0.115
White, Non-Hispanic	Other	0.660	0.204	0.104	0.372	0.604	0.235
Black, Non-Hispanic	Mexican-American	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.042	< 0.0005
Black, Non-Hispanic	Other	0.010	< 0.0005	0.050	< 0.0005	0.039	< 0.0005
Mexican-American	Other	0.948	0.258	0.183	0.567	0.581	0.773

Table 16. Statistical significance tests comparing the medians of blood lead in children ages 1 to 5, between pairs of race/ethnicity/income groups at different income levels, for 2005-2008.

		P-VALUES	
RACEINC1	**RACEINC2**	**Unadjusted**	**Adjusted (for age, gender)**
White, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	0.355	0.002
White, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	0.522	0.704
White, Non-Hispanic, < PL	Mexican-American, >= PL	0.412	< 0.0005
White, Non-Hispanic, < PL	Other, >= PL	0.270	< 0.0005
Black, Non-Hispanic, < PL	White, Non-Hispanic, >= PL	< 0.0005	< 0.0005
Black, Non-Hispanic, < PL	Black, Non-Hispanic, >= PL	< 0.0005	< 0.0005
Black, Non-Hispanic, < PL	Mexican-American, >= PL	< 0.0005	< 0.0005
Black, Non-Hispanic, < PL	Other, >= PL	< 0.0005	< 0.0005
Mexican-American, < PL	White, Non-Hispanic, >= PL	0.001	0.162
Mexican-American, < PL	Black, Non-Hispanic, >= PL	0.937	0.126
Mexican-American, < PL	Mexican-American, >= PL	0.007	0.010
Mexican-American, < PL	Other, >= PL	0.015	0.013
Other, < PL	White, Non-Hispanic, >= PL	0.008	0.126
Other, < PL	Black, Non-Hispanic, >= PL	0.195	0.557
Other, < PL	Mexican-American, >= PL	0.012	0.016
Other, < PL	Other, >= PL	0.009	0.030

Conclusion

This memorandum has presented statistical methods to test for trends, year-to-year differences, and demographic group differences in NHIS and NHANES data. The NHIS statistical methods using logistic regression models were tested on the asthma attack prevalence data but are applicable to all NHIS analyses that use the prevalence of a disease or condition. The NHANES statistical methods using weighted linear regression models were tested on the blood lead median data but are applicable to all NHANES analyses of body burden concentration percentiles. For some analyses, it will be necessary to revise the age group definitions. The unadjusted analyses are compared to adjusted analyses that account for possible confounding effects of other demographic variables, and to stratified analyses that account for possible interactions between the trends (or year-to-year changes) and the demographic group effects.

APPENDIX: NHANES PERCENTILE RELATIVE STANDARD ERROR CALCULATIONS

The uncertainties of the median and 95th percentile values were calculated using a revised version of the CDC method given in CDC 2005[15], Appendix C, and the SAS® program provided by CDC. The method uses the Clopper-Pearson binomial confidence intervals adapted for complex surveys by Korn and Graubard (see Korn and Graubard, 1999[16], p. 65). The following text is a revised version of the Appendix C.

Step 1: Use SAS® Proc Univariate to obtain a point estimate P_{SAS} of the percentile value. Use the Weight option to assign the exact correct sample weight for each chemical result.

Step 2: Use SUDAAN® Proc Descript with Taylor Linearization DESIGN = WR (i.e., sampling with replacement) and the proper sampling weight to estimate the proportion (p) of subjects with results less than and not equal to the percentile estimate P_{SAS} obtained in Step 1 and to obtain the standard error (se_p) associated with this proportion estimate. Compute the degrees-of-freedom adjusted effective sample size

$$n_{df} = (t_{num}/t_{denom})^2 \, p(1 - p)/(se_p{}^2)$$

where t_{num} and t_{denom} are 0.975 critical values of the Student's t distribution with degrees of freedom equal to the sample size minus 1 and the number of PSUs minus the number of strata, respectively. Note: the degrees of freedom for t_{denom} can vary with the demographic sub-group of interest.

Step 3: After obtaining an estimate of p (i.e., the proportion obtained in Step 2), compute the Clopper-Pearson 95% confidence interval ($P_L(x,n_{df})$, $P_U(x,n_{df})$) as follows:

$$P_L(x,n_{df}) = v_1F_{v1,v2}(0.025)/(v_2 + v_1F_{v1,v2}(0.025))$$
$$P_U(x,n_{df}) = v_3F_{v3,v4}(0.975)/(v_4 + v_3F_{v3,v4}(0.975))$$

where x is equal to p times n_{df}, $v_1 = 2x$, $v_2 = 2(n_{df} - x + 1)$, $v_3 = 2(x + 1)$, $v_4 = 2(n_{df} - x)$, and $F_{d1,d2}(\beta)$ is the β quantile of an F distribution with d1 and d2 degrees of freedom. (Note: If n_{df} is greater than the actual sample size or if p is equal to zero, then the actual sample size should be used.) This step will produce a lower and an upper limit for the estimated proportion obtained in Step 2.

Step 4: Use SAS Proc Univariate (again using the Weight option to assign weights) to determine the chemical percentile values P_{CDC}, L_{CDC} and U_{CDC} that correspond to the proportion p obtained in Step 2 and its lower and upper limits obtained in Step 3. Do not round the values of p and the lower and upper limits. For example, if p = 0.4832, then P_{CDC} is the 48.32'th percentile value of the chemical. The alternative percentile estimates P_{CDC} and P_{SAS} are not necessarily equal.

Step 5: Use the confidence interval from Step 4 to estimate the standard error of the estimated percentile P_{CDC}:

$$\text{Standard Error } (P_{CDC}) = (U_{CDC} - L_{CDC}) / (2t_{denom})$$

Step 6: Use the estimated percentile P_{CDC} and the standard error from Step 4 to estimate the relative standard error of the estimated percentile P_{CDC}:

$$\text{Relative Standard Error (\%)} = [\text{Standard Error } (P_{CDC}) / P_{CDC}] \times 100\ \%$$

The tabulated estimated percentile in the ACE reports is the value of P_{SAS} given in Step 1. The relative standard error is given in Step 6, using P_{CDC} and its standard error.

[15] CDC Third National Report on Human Exposure to Environmental Chemicals. 2005
[16] Korn E. L., Graubard B. I. 1999. *Analysis of Health Surveys.* Wiley.

The relative standard error depends upon the survey design. For this purpose, the public release version of NHANES includes the variables SDMVSTRA and SDMVPSU, which are the Masked Variance Unit pseudo-stratum and pseudo-primary sampling unit (pseudo-PSU). For approximate variance estimation, the survey design can be approximated as being a stratified random sample with replacement of the pseudo-PSUs from each pseudo-stratum; the true stratum and PSU variables are not provided in the public release version to protect confidentiality.