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Adjusting National Health and Nutrition Examination Survey Sample Weights for Women of Childbearing Age

Vital and Health Statistics

Series 2, Number 157

May 2013

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Center for Health Statistics

Suggested citation

Parker J, Branum A, Axelrad D, Cohen J. Adjusting National Health and Nutrition Examination Survey sample weights for women of childbearing age. National Center for Health Statistics. Vital Health Stat 2(157). 2013.

Library of Congress Cataloging-in-Publication Data

Adjusting NHANES sample weights for women of childbearing age.
p. ; cm.— (Vital and health statistics ; Series 2, Data evaluation and methods research ; no. 157) (DHHS publication ; no. (PHS) 2013–1357)
“May 2013.”
Includes bibliographical references and index.
ISBN 0–8406-0657–5 (alk. paper)
I. National Center for Health Statistics (U.S.) II. Series: Vital and health statistics. Series 2, Data evaluation and methods research ; no. 157. III. Series: DHHS publication ; No. (PHS) 2013–1357. 0276–4733
[DNLM: 1. National Health and Nutrition Examination Survey (U.S.) 2. Fertility—United States. 3. Maternal Nutritional Physiological Phenomena—United States. 4. Body Weight—United States. W2 A N148vb no.157 2013]
RA407.3
614.4’273021—dc23 2013013427

For sale by the U.S. Government Printing Office
Superintendent of Documents
Mail Stop: SSOP
Washington, DC 20402–9328
Printed on acid-free paper.

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Data Evaluation and Methods Research

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Center for Health Statistics

Hyattsville, Maryland
May 2013
DHHS Publication No. 2013–1357

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Acknowledgment

The authors of this report gratefully acknowledge the computer programming assistance of Xiang Liu, M.S., of the National Center for Health Statistics.

Abstract

Background

Maternal risk factors have been tabulated for women of childbearing age using defined age ranges. However, statistics for factors strongly related to age may be overly influenced by values for the youngest and oldest women in a range, because pregnancies are most likely for ages 20–35.

Objective

This report evaluates adjustment methods, based on the probability of pregnancy, for calculating estimates of risk factors for women of childbearing age.

Methods

Adjusted and unadjusted estimates for environmental and nutritional variables were calculated from the 1999–2008 National Health and Nutrition Examination Survey (NHANES) for women aged 16–49. U.S. births were used to determine the probability of pregnancy.

Results

Adjusted and unadjusted estimates differed for some, but not all, examined variables. More marked differences were observed for the environmental variables compared with the nutritional variables. Adjusted estimates were within about 5% of the unadjusted estimates for the nutritional variables. Adjusted geometric means for lead and mercury were about 7%–10% lower, and for polychlorinated biphenyl (or PCB) about 25% lower, than their respective unadjusted geometric means. With few exceptions, different adjustment methods led to similar estimates.

Conclusion

When calculating statistics for women of childbearing age, the decision to adjust for age or not to adjust appears to be more important than the choice of adjustment method. Although the results suggest only small differences among adjustment methods, approaches based on the NHANES design and sample weighting methodology may be the most robust for other applications.

Keywords: NHANES • summary measures • indicators • direct adjustment

Adjusting National Health and Nutrition Examination Survey Sample Weights for Women of Childbearing Age

by Jennifer Parker, Ph.D., and Amy Branum, Ph.D., National Center for Health Statistics; Daniel Axelrad, M.P.P., U.S. Environmental Protection Agency; and Jonathan Cohen, Ph.D., ICF International

Introduction

Conception and healthy pregnancy depend on the health of the mother. While studies of pregnant women can inform their nutritional status and other exposures, these studies cannot capture the corresponding health status of those who are not pregnant at the time of the study but who may become pregnant in the future, or those who are having difficulty becoming pregnant. In addition, pregnant women as a group present many ethical and logistical challenges to traditional medical and epidemiologic research (1,2). Furthermore, sample sizes for studies of pregnant women are much lower than for studies of women of childbearing age, affecting statistical precision and power. Broadening populations of interest to women of childbearing age can still yield important information about various environmental and nutritional exposures, such as vitamin D and folate status or body burdens of mercury and cadmium, and their impact on pregnancy and birth outcomes. Of the Healthy People 2020 objectives, women of childbearing age are a target population for three indicators related to family planning (3) and maternal, infant, and child health (4). A recent U.S. Environmental Protection Agency (EPA) report describing potential risks to children from environmental exposures, America's Children and the Environment (ACE), includes several indicators of exposures to women of childbearing age (5).

However, the best approach for obtaining exposure estimates from national samples for women of childbearing age is unknown, particularly when making estimates using national complex sample surveys. The National Health and Nutrition Examination Survey (NHANES), for example, collects a wide array of examination and laboratory information useful for describing the health of this group. Among other design features, NHANES data files include sample weights for calculating nationally representative estimates (6). However, to define women of childbearing age, or childbearing potential, a standard age range (often ages 16–49) is typically chosen. The age-range approach gives too much ''weight'' to younger and older women who are more commonly represented in the overall population of U.S. women but who are also less likely to give birth (7,8). Consequently, estimates based on this approach will represent U.S. women within the age range, but also may be influenced by high or low values at the beginning or end of the age range and not necessarily represent those who are more likely to give birth. In addition, the resulting estimates may be sensitive to the choice of age range—making comparisons across analyses with different ranges difficult—and information for women outside the range is not used.

A recent journal article by Axelrad and Cohen (9) described one approach for handling this issue for calculating summary statistics from NHANES. Their objective was to evaluate methods for producing national exposure estimates for women of childbearing age for a selection of the ACE indicators. In the article, Axelrad and Cohen examined different methods for estimating risk factors for women of childbearing age: a) restricting the age range to include women more likely to have children, and b) adjusting the NHANES public-use sample weights using national birth rates. They concluded that adjusting the NHANES public-use sample weights using birth rates calculated by single year of age and race and ethnicity categorized into four groups (non-Hispanic white, non-Hispanic black, Mexican American, all other races and ethnicities) produced reasonable estimates. This was the approach used to calculate exposure estimates for women of childbearing age in the most recent ACE report (5).

To extend this work in the context of national health survey data, two methods for calculating estimates for women of childbearing age are examined using the 1999–2008 NHANES. The first method—adjustment of the NHANES sample weights by U.S. birth rates—reweights the sample weights six ways, including those used by Axelrad and Cohen (9). For the second method—direct standardization—estimates are derived from the NHANES public-use sample weights with subsequent adjustments to standard populations defined by the number of U.S. births. The direct-standardization approach is similar to the age standardization often used for comparing health outcomes for two populations with different age distributions (10).

This report shows that estimates calculated using different adjustment approaches are similar. Although results are presented for unadjusted estimates alongside adjusted estimates, this evaluation was not designed to determine the conditions under which adjustment should be done. Nevertheless, comparisons between unadjusted and adjusted estimates indicate that adjustment has more of an impact for some variables than for others.

Methods

Data

National Health and Nutrition Examination Survey

The NHANES program began in the early 1960s and has been conducted as a series of surveys focusing on different population groups or health topics. In 1999, the survey became a continuous program that includes an interview in the household followed by a physical examination in a mobile examination center (MEC). NHANES is a representative cross-sectional sample of the U.S. civilian noninstitutionalized population that is selected using a complex, multistage probability design. Detailed descriptions of the NHANES sample designs are available elsewhere (6). Data for 1999–2008 were used for this analysis because some of the variables examined were not available for later survey releases at the time of this analysis.

Nationally representative estimates and standard errors for reported and measured health variables can be calculated using the NHANES sample weights and design variables available from the survey (6). Different public-use NHANES sample weights are created for the sample participating in the NHANES interview, the sample in the MEC, and subsamples for some specific survey elements (e.g., fasting blood draws). The original NHANES examination weights are used for this report. Sample weights for NHANES participants incorporate adjustments for unequal selection probabilities and certain types of nonresponse, as well as an adjustment to independent estimates (known as control totals) of population sizes for specific age, sex, and race and ethnicity categories. Age categories used in the control totals covering women of childbearing age are 16–19, 20–39, and 40–59. Race and ethnicity categories for control totals for the 1999–2006 NHANES are non-Hispanic black, Mexican American, and non-Hispanic white/other (comprising all other races and ethnicities). For the 2007–2008 NHANES, the race and ethnicity categories are slightly different: non-Hispanic black, Hispanic, and non-Hispanic white/other.

Nutritional and environmental variables—Several NHANES laboratory variables were used in this report, many measured in blood collected as part of the MEC exam (11). Concentrations of lead, total mercury, and polychlorinated biphenyl (PCB) were measured in whole blood using plasma mass spectrometry. More detail on specimen collection and laboratory methods can be found elsewhere for lead (12), total mercury (12), and PCB (13). Although measurement of mercury changed over the time period, leading to slightly differing limits of detection (LODs), the data have been found to be reasonably comparable across survey releases (14). The calculation of PCB levels was based on multiple laboratory measurements (15) (see Appendix I) and follows the approach used in ACE (5). PCB measurements were available for NHANES 2001–2004; summary estimates for PCB in this report are calculated using the examination weights created for the one-third subsample. The three environmental variables of lead, mercury, and PCB were selected because of their possible effects on infant outcomes and childhood neurodevelopmental outcomes (16–21), and their differing levels by age (9,21).

Nutritional NHANES laboratory variables included calcium, folate, iron, and vitamin D. Iron is measured for NHANES participants aged 3–5 years and females aged 12–59 using a timed end-point method (22). Vitamin D is measured using a two-step assay procedure (23). Calcium is measured as part of the biochemistry profile using indirect ion-selective electrode methodology (24). Serum folate was measured using radioassay (25); because the type of radioassay changed from 1999–2006 to 2007–2008, serum folate values are adjusted using a regression equation provided by NHANES (25). In addition, body mass index [BMI = height (meters)/weight (kilograms)^2] was analyzed (26). These variables were chosen, in part, because pregnant women are encouraged to consume a threshold of these nutrients and are monitored for weight and weight gain throughout pregnancy.

Study population—Women aged 16 to 49 who participated in the MEC exam in the 1999–2008 surveys were included (Table 1). Some laboratory measures were not available for all years. Vitamin D was measured for 1999–2006, but the data for 2007–2008 were not available at the time of this analysis. PCB data are available for a one-third sample of the 2001–2002 and 2003–2004 survey releases; PCB data from 1999–2000 were not used because of the high frequency of samples with values below the LOD. Some measures were missing for some NHANES participants (Table 2). No adjustments for missing values were made.

Birth and population data

Birth data—U.S. natality data for 1999–2008 from the National Center for Health Statistics (NCHS) were used to calculate birth rates and to obtain birth totals for the direct standardization described below (27). The natality files contain health and demographic information on all births that occur in the United States each year. During 1999–2008, approximately 3.9 million to 4.3 million births occurred annually. Of the 4.3 million births in 2007, about 25,000 births were to mothers under age 16 (less than 0.6%) and about 500 births to mothers over age 49 (27).

Population estimates—Civilian noninstitutionalized population estimates for females were used from the Current Population Survey (CPS), estimated at the midpoint of each NHANES data release. These are the estimates used to create the NHANES sample weights; for details, see http://www.cdc.gov/nchs/nhanes/response_rates_cps.htm (28). These estimates are used rather than total population estimates, which are usually used to calculate national birth rates (27), to better align with the NHANES race and ethnicity domains.

Adjusted Estimates

Adjusted means and standard errors were calculated two ways, first through adjustment of the NHANES sample weights and, secondly, using direct standardization. Percentiles were calculated using only the adjusted sample weights because these estimates and their standard errors are not readily calculated using direct standardization.

NHANES sample weight adjustment

For sample weight adjustment, the public-use NHANES sample weights were multiplied by birth rates calculated for different age-group definitions, race and ethnicity subgroups, and survey releases. Weights were adjusted by age and race and ethnicity because the age distribution of births differs by race and ethnicity. To calculate birth rates, age was used both in single years and categorized into seven 5-year intervals: 16–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49. Race and ethnicity were categorized two ways. The first corresponds to the categorization used by ACE (5), with four subgroups—Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities. The second way corresponds to the NHANES sampling domains for 1999–2006, with three subgroups—Mexican American, non-Hispanic black, and white/other. Birth rates were estimated by dividing the number of births to mothers in each age and race-and-ethnicity category by the corresponding CPS population estimate for females in that category.

Birth rates used in the adjustments were calculated according to the following six categorizations based on the definitions above:

1. Single year of age
2. Five-year age groups
3. Single year of age and race and ethnicity (four subgroups)
4. Single year of age and race and ethnicity (three subgroups)
5. Five-year age group and race and ethnicity (four subgroups)
6. Five-year age group and race and ethnicity (three subgroups)

For each survey respondent, the adjusted sample weight is the product of the public-use NHANES examination sample weight and the birth rate corresponding to the respondent's year of NHANES participation, age, and race and ethnicity.

$$Adj\ weight_{ijkl} = (NHANES\ sample\ weight_{ijk}) * birth\ rate_{ijkl}$$

where

i corresponds to each NHANES data release: 1999–2000, 2001–2002, 2003–2004, 2005–2006, and 2007–2008;

j indicates age group;

k indicates race and ethnicity;

and

l indicates which of the six methods above is used.

Direct standardization

For direct standardization, estimated means and standard errors were calculated for each age group using the public-use NHANES examination sample weights and then combined into a standardized estimate; as noted, percentiles and their standard errors are less readily estimated using this approach and were not computed. For comparison, two standardizations were used: births in four maternal age groups (under age 20, 20–29, 30–39, and 40–49) and the seven 5-year age groups (16–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49) detailed earlier. The overall numbers of births for all years combined were used for the age adjustment, rather than for the 2-year survey releases, for simplicity.

For an estimated mean, the overall age-standardized mean can be calculated as the weighted sum of the *i* age-group specific means, where the weights indicate the proportion of births in each age group *i*. In applications to NHANES and other complex surveys, age-group specific means and variances are obtained using methods for complex surveys that use the original sample weights and design information:

$$\bar{x} = \sum w_i \bar{x}_i$$

The standard error follows:

$$se(\bar{x}) = \sqrt{\sum w_i^2 var(\bar{x}_i)}$$

Analysis

Before evaluating weighting methods, the NHANES nutritional and environmental variables were examined to determine whether log transformation would be appropriate. Correlations of these variables with age were calculated using the original public-use NHANES examination weights. Statistical significance of correlations was determined using univariate regression equations accounting for the survey design, with each NHANES variable as the outcome (left side) and age as the predictor (right side) (29).

Adjusted sample weights—Next, unweighted correlations among the adjusted sample weights were examined, and their unweighted summary statistics (means, variances, and percentiles) were inspected. Adjusted sample weights were compared overall and by race and ethnicity.

Adjusted estimates—Using the two adjustment approaches described earlier, summary statistics for the NHANES variables were examined.

Statistics for calcium and iron were obtained using the untransformed variables. Summary statistics for lead, mercury, PCB, vitamin D, folate, and BMI were calculated using log-transformed variables to reduce the effect of the skewness. Geometric means and standard errors for these variables are presented after exponentiation of the log-transformed estimates to ease comparisons; standard errors for these variables were calculated using a standard equation for geometric variances via the delta method (30). If $\overline{ln(y)}$ and $se(ln(y))$ are the estimated mean and standard error of the natural logarithm of Y, then the geometric mean of Y and its standard error can be estimated as:

$$\hat{g} = e^{\overline{ln(y)}}$$

$$\widehat{gs} = \hat{g} * se(ln(y))$$

SUDAAN (31) and Stata (32) software were used so that additional features of the NHANES sample design—the strata and primary sampling units or PSUs—could be incorporated in the estimation along with the adjusted weights; PROC DESCRIPT (SUDAAN) was used for direct standardization. Percentiles were obtained using SAS computer code used in the "Fourth National Report on Human Exposure to Environmental Chemicals" (33).

Comparisons between the unadjusted and adjusted estimates and among different adjustment methods were not tested for statistical significance because the estimates are not independent. Consequently, statements should be considered as observations rather than as conclusions of a statistical test.

Results

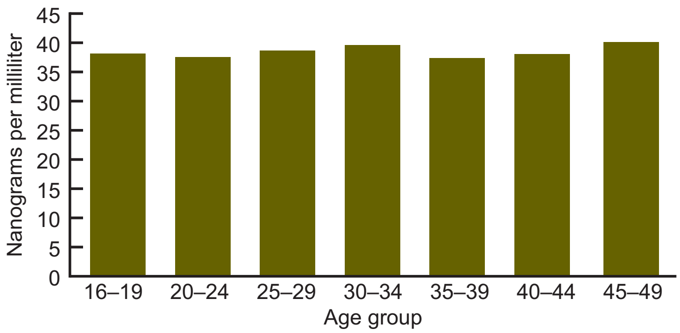
A total of 9,422 women aged 16–49 were eligible for this analysis (Table 1). The number of women with data for each analytic variable, and the weighted correlation between each analytic variable and age, are shown in Table 2. Of the selected NHANES variables, the weighted correlation between age and PCB (log scale) was highest (0.65), followed by the correlations between age and lead (log scale, 0.32); correlations between age and mercury (log scale) and BMI (log scale) were around 0.20. Calcium, vitamin D, and iron were negatively correlated with age. With the exception of folate, correlations between the analytic variables and age were statistically significant ($p < 0.05$). Figure 1 shows estimates for the nutrition variables, and Figure 2 shows estimates for lead, PCB, and mercury, by age group; the data table for these figures is in Appendix II.

Table 3 shows unweighted distributional statistics for the adjusted sample weights, compared with corresponding values for the public-use NHANES examination sample weights. As expected, the adjusted sample weights are considerably smaller than the original sample weights due to multiplication by the birth rate. The ranges, approximated by the differences between the 95th and 5th percentiles, and variability of the adjusted sample weights, are relatively greater than those of the original sample weights. For example, the median of the original sample weight is approximately one-fourth of the corresponding 95th percentile (about 26,000 compared with 106,000), whereas the medians of the adjusted weights are about one-tenth of the corresponding 95th percentiles. The means of the adjusted weights using the 5- and single-year age adjustments were similar. For both single- and 5-year age adjustment, 95th percentiles and standard deviations of adjusted sample weights using the three NHANES race-and-ethnicity categories were about 20% higher than those using four race-and-ethnicity categories. The 95th percentiles and standard deviations of the adjusted weights using single year of age adjustment were close to the corresponding statistics using the 5-year adjustment (within 1%–2%).

Correlations among the adjusted sample weights were high, greater than 0.95 for all pairwise correlations (Table 4). The correlations between each of the adjusted sample weights and the original sample weight were generally lower, around 0.55–0.65 (Table 4). Statistical tests for these correlations were not done because the adjusted sample weights are not independent.

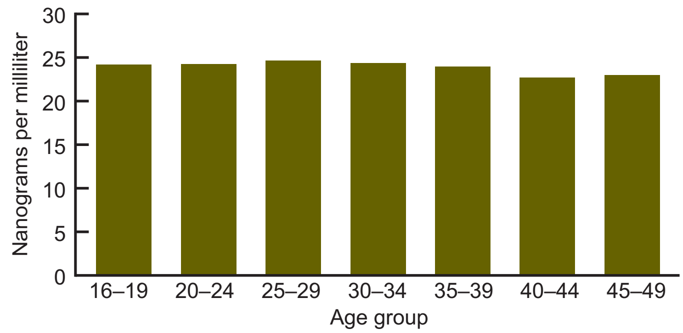
Tables 5 and 6 show the weighted summary statistics for the environmental and nutritional variables, respectively, using the different weights and calculated using direct standardization. For some variables, statistics using the original sample weight were different from those using the adjusted weights. The effect of adjustment on the

A. Folate



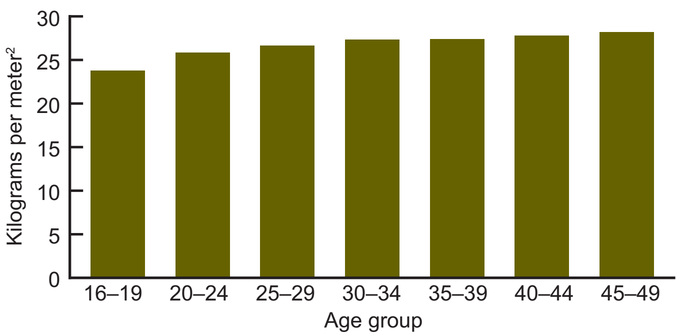
NOTE: Estimates are geometric means.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 2001–2008.

B. Vitamin D



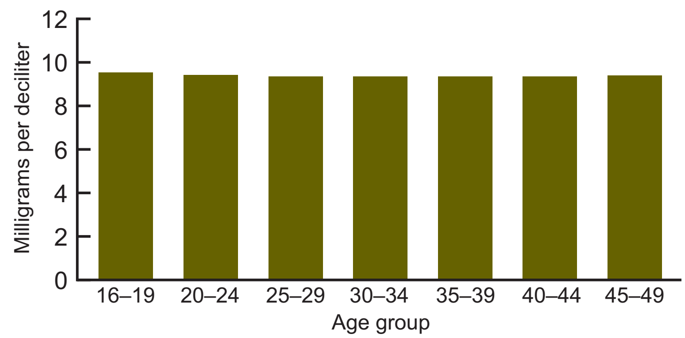
NOTE: Estimates are means.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 2001–2006.

C. Body mass index



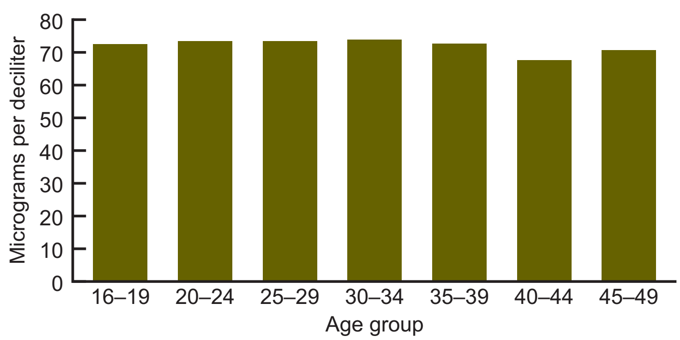
NOTE: Estimates are geometric means.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 1999–2008.

D. Calcium



NOTE: Estimates are means.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 1999–2008.

E. Iron



NOTE: Estimates are geometric means.
SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 1999–2008.

Figure 1. Means (or geometric means) of nutritional factors for women aged 16–49, by age group: National Health and Nutrition Examination Survey, 1999–2008 (selected years)

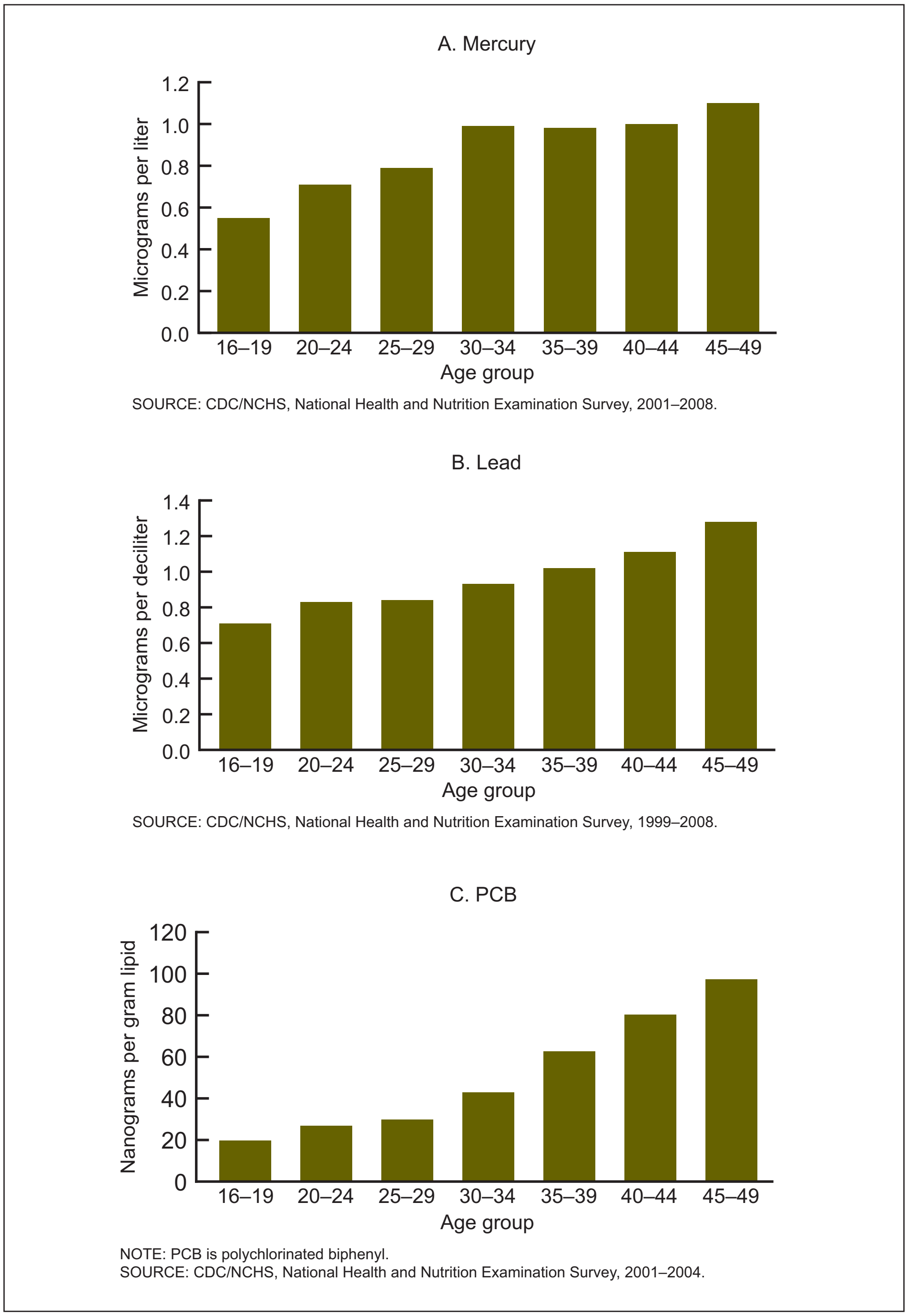


Figure 2. Geometric means of environmental factors for women aged 16–49, by age group: National Health and Nutrition Examination Survey, 1999–2008 (selected years)

environmental variables was more pronounced than on the estimates of the nutritional variables; however, unexpectedly, the differences between estimates calculated using the original sample weight and the adjusted weights were not always greater for the variables more highly correlated with age than those less correlated with age. For example, the correlations between age and BMI, and age and calcium, were relatively high compared with those for other nutritional factors (about 0.19 and –0.09, respectively), yet the adjusted geometric mean (BMI) and mean (calcium) were similar to (or the same as) unadjusted estimates. However, adjusted geometric means for lead and mercury were roughly 8% lower than the unadjusted geometric means, and adjusted geometric means for PCB were more than one-fourth lower than the unadjusted geometric mean.

Standard errors of the geometric means or means for the nutritional variables using the adjusted sample weights were most often larger than the corresponding standard errors calculated using the unadjusted sample weights—for example, about 10% larger for the standard error for BMI and vitamin D, and more than one-third larger for iron. Compared with standard errors for the geometric means using the unadjusted sample weights, standard errors using the adjusted sample weights were similar for mercury, about 5% higher for lead, and about 20% lower for PCB.

Geometric means and means calculated using adjusted sample weights were similar across adjustment methods. Results from direct standardization were similar to those for the sample weight adjustments. Although there were small differences, these similarities were apparent for both the environmental and nutritional variables (Tables 5 and 6).

Patterns for the 85th and 95th percentiles were similar to those for means and geometric means for the environmental (Table 7) and nutritional (Table 8) variables. The 95th percentiles for PCB using the adjusted weights are approximately 40% lower than the 95th percentiles using the original weights (Table 8).

The impact of using adjusted sample weights to obtain estimates differed among the race-and-ethnicity groups (Tables 9 and 10). For example, the impact of adjustment on the geometric mean of mercury was greater for black than for white/other or Mexican-American women. Estimates generally did not vary among the adjustment approaches within race-and-ethnicity categories. Using race and ethnicity to adjust the weights had a slightly larger effect on estimates of the environmental variables and folate for non-Hispanic black women compared with women in the other groups; estimates using either the three- or four-category race-and-ethnicity adjustment were 2%–10% lower than those using only age adjustment among non-Hispanic black women. However, this effect was not readily apparent for the other nutritional variables nor for the other race-and-ethnicity subgroups.

Discussion

Several approaches were compared for adjusting estimates of nutritional and environmental variables to better correspond to those women who are most likely, based on age, to give birth. As in Axelrad and Cohen (9), this report demonstrates that adjustment can affect some estimates for women aged 16–49. However, summary statistics, including measures of variability, were not very sensitive to the adjustment method used.

Although it was anticipated that adjustment would affect variables more strongly correlated with age, this was not fully supported by the results. For example, the correlations with age for mercury and BMI were similar (about 0.2); however, adjustment led to geometric means about 7% lower for mercury but similar for BMI (about 1.5% lower). Other factors, including the variance of the variable, the relative standard error of the estimate, and the age distribution of women in the sample, likely affect the impact of sample weight adjustment; however, these and other factors that may affect the impact of adjustment were not directly evaluated here.

Direct standardization and adjusting sample weights led to similar results. The similarity of estimates of means and standard errors between these approaches is attributable to the fact that these calculations are mathematically equivalent and that, in general, results from an application would differ only due to differences in adjustment groupings, in the handling of missing data, and in the populations used to calculate birth rates. In this report, application of the direct-standardization method combined total births across all survey years, whereas the sample weights were adjusted separately for each data release. In comparable direct age-adjustment applications, a standard population is generally used; currently, populations based on year 2000 estimates are used for NCHS reports (34). Although there is no standard population for women of childbearing age, using the combination of births across years to obtain reference values is in line with using a single-year reference. For a particular data analysis, any observed differences between estimates obtained from direct standardization using a single reference and sample-weight adjustment using year- or data release-specific references could be affected by the length of the time period for the analysis and changes in the age distribution of births over the time period.

The extension of the Axelrad and Cohen paper (9) was motivated by the question of whether an adjustment to the sample weights more consistent with the underlying NHANES sample design, or using direct standardization, would be more robust. Direct standardization enables the user to obtain age-specific statistics with the unmodified public-use sample weights. It was posited that adjustment using larger age categories, rather than single year of age, and race and Hispanic origin categories in line with the NHANES design would lead to more stable adjusted weights and, as a result, more stable estimates of risk factors. The NHANES sample design is based on oversampling population subgroups. Although the subgroups can change over time, generally these include specific race and Hispanic-origin groups and age categories. The stratified cluster design and oversampling are intended to provide stable estimates for selected population subgroups while controlling for the high costs of data collection. Very generally, sample weights are initially calibrated based on the probability of selection into the sample and subsequent response. Initial weights are further calibrated to external population control totals based on specific categories of age, sex, and other characteristics, often race and ethnicity. Weights are evaluated for extreme values and can be trimmed to meet prior specifications. The NHANES race domains used in this report (non-Hispanic black, Mexican American, white/other) and broad age categories are based on the post-stratification categories used to calibrate the weights to national civilian noninstitutionalized population totals. For black and Mexican-American women aged 16–49, for example, the age categories are 16–19, 20–39, and 40–59; for the white/other race group, the 20–39 and 40–59 age groups are divided into 20–29, 30–39, 40–49, and 50–59. More detail on NHANES weights can be found in a recent report by Curtin and colleagues (6).

The birth rates in this report, calculated for single-year and 5-year groups, are more specific than the post-stratification categories used to calibrate the initial sample weight. Similarly, the four race-and-ethnicity categories used by EPA in ACE are more specific than the three used to calibrate the initial sample weights. For this evaluation, summary statistics are examined for the three NHANES race-and-ethnicity domains but the ‘‘all other races and ethnicities’’ group used for ACE are not specifically examined. On the one hand, the ‘‘all other race and ethnicities’’ group is heterogeneous, combining people who identify, for example, within Asian, Pacific Islander, and other Hispanic subgroups, so that birth rates and subsequent inferences for this combined group may be difficult to interpret. On the other hand, statistics for ‘‘all other race and ethnicities’’ may identify potential issues for further investigation. For example, analysis of the NHANES data has found that women of ‘‘all other races and ethnicities’’ have higher blood mercury levels than women who are white, black, or Mexican American (35,36), suggesting one or more of the specific subgroups combined in the ‘‘all other races and ethnicities’’ group is at increased risk.

There is trade-off, known as a bias variance trade-off, when creating sample weights that carries over to methods for reweighting; that is, more precise, yet more variable, sample weights can lead to estimates with lower bias but higher variance. For the nutritional and environmental factors evaluated in this report, no patterns were observed that suggested strong trade-offs between using coarser (e.g, 5-year age groups only) and more precise (e.g., single year of age with four race-and-ethnicity categories) adjustments for the sample weights.

Civilian noninstitutionalized population estimates based on CPS estimates were used as denominators for the calculation of birth rates; although the conclusions of this report were expected to be the same, the adjusted statistics reported in the tables could differ slightly if different population estimates were used. Similarly, population estimates obtained by summing the sample weights within the target groups would have the advantage of being better calibrated to NHANES and would not require obtaining population estimates from another source; because the direct standardization used counts of births, not birth rates, using summed weights would connect direct standardization and sample weight adjustment more closely. On the other hand, as the CPS estimates, using the summed sample weights as denominators would also differ from the total population on which the birth counts are based. Methods that incorporate other factors related to the probability of becoming pregnant may provide better estimates. Further, the use of population estimates or birth counts was not considered for estimates from single NHANES data releases, which produce statistics with more variability.

Direct-standardization approaches have the advantage of being relatively simple to implement and describe. In addition, if the group-specific estimates and their standard errors are available, the adjustment does not require use of the original data. This method relies on external population totals and, in this case, available counts of births by mother's age and other characteristics, like race and ethnicity. Weighted averages of the category-specific means can be easily combined in a spreadsheet, and variance estimates can readily follow. In addition, the sample weights calibrated by the survey statisticians for public-data release remain intact. However, care needs to be taken to assure categories with sufficient sample size and precision for direct standardization. Further, direct-standardization methods do not work as easily for percentiles and other nonparametric statistics using standard software, so the statistical expertise needed to obtain confidence intervals using this approach may negate the above-mentioned advantages of ease and transparency.

Although little impact is shown from the choice of adjustment methods for the measured variables used in this study, other uses of adjusted weights may be more sensitive. For example, properties were not examined of the adjusted weights or estimates derived from direct standardization for subgroups defined by demographic characteristics such as income or education, or by other health conditions. However, applying one of the approaches examined here, or another statistical method using birth rate information, reduces the influence of specific age ranges to define women of childbearing age on inferences. Defining a population using an age range can reduce the generalizability of findings across studies that use different ranges. Further, fixed age ranges produce truncated age distributions and loss of information beyond the range.

The similarity of the estimates obtained using different adjustment approaches, combined with small differences between the adjusted and unadjusted estimates for many variables, suggests that methods for using birth rate information to modify statistics for women of childbearing age in NHANES are robust. The decision to apply an adjustment appears to have more impact than the actual adjustment approach. Because the purpose of this report was to compare possible adjustment methods, the conditions under which adjustment would be important were not directly evaluated. The findings for PCB, which is the variable most strongly correlated with age and has a relatively high standard error, demonstrate the potential importance of the decision to adjust or not adjust for some variables.

NCHS does not currently plan to adopt one of these reweighting methods for regular use. A recent NCHS report describing lead and mercury levels for pregnant women, for example, compared some estimates for pregnant and nonpregnant women and used direct standardization, as described above, to adjust for the differing age distribution between the two groups (37). Although the examples shown in this report show little impact from the choices of adjustment on the estimates, if adjustment is required for future projects, NCHS will use methods consistent with the NHANES design, such as the coarser age categories and race-and-ethnicity categorizations in line with the sampling domains. Researchers are advised to consult statistical advice for their particular research or reporting objectives before adjusting NHANES sample weights.

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Table 1. Age and race distribution of women aged 16–49, by age group: National Health and Nutrition Examination Survey, 1999–2008

NHANES race domain and age group (years)[1]	n^2	Weighted percent
Non-Hispanic white/All other groups		
16–19	932	8.27
20–24	668	11.16
25–29	684	10.11
30–34	675	10.88
35–39	615	11.96
40–44	567	12.51
45–49	556	12.57
Non-Hispanic black		
16–19	746	1.55
20–24	281	2.12
25–29	226	1.76
30–34	254	2.14
35–39	231	2.04
40–44	254	1.90
45–49	256	2.00
Mexican American		
16–19	825	1.12
20–24	381	1.72
25–29	309	1.46
30–34	273	1.46
35–39	223	1.28
40–44	268	1.13
45–49	198	0.88

[1]Categories used when designing the National Health and Nutrition Examination Survey (NHANES) sample and creating the public-use sample weights for 1999–2006.

[2]Sample sizes may be lower for some nutritional and environmental variables.

Table 2. Summary statistics (weighted) for analysis variables for women aged 16–49: National Health and Nutrition Examination Survey, 1999–2008

Variable	*n*	Mean	Standard error	Geometric[1] mean	Geometric[1] standard error	Correlation with age[2]
Environmental						
Mercury (µg/L)	8,830	1.50	0.06	0.87	0.03	0.20
Lead (µg/dL)	8,845	1.16	0.02	0.96	0.01	0.32
PCB[3] (ng/g lipid)	1,164	66.02	2.13	46.54	1.78	0.65
Nutritional						
Folate (ng/mL)	8,765	43.17	0.04	38.50	0.42	0.02
Vitamin D (ng/mL)	5,472	23.80	0.37	– – –	– – –	–0.05
Body mass index (kg/m^2)	9,238	27.67	0.14	26.82	0.12	0.19
Calcium (mg/dL)	8,722	9.38	0.01	– – –	– – –	–0.09
Iron (µg/dL)	8,720	81.31	0.57	71.90	0.50	–0.04

– – – Data not available.

[1]For left-skewed variables.

[2]For variables where geometric mean is shown, the correlation is on the log scale.

[3]Polychlorinated biphenyl.

NOTES: Examination weights are used from the National Health and Nutrition Examination Survey. Data reflect selected years: PCB is calculated for one-third of the sample for 2001–2004, and vitamin D is calculated for 2001–2006. µg/L is micrograms per liter, µg/dL is micrograms per deciliter, ng/g lipid is nanograms per gram lipid, ng/mL is nanograms per milliliter, kg/m^2 is kilograms per meter^2, and mg/dL is milligrams per deciliter.

Table 3. Distribution of original and adjusted sample weight variables (unweighted statistics) for women aged 16–49: National Health and Nutrition Examination Survey, 1999–2008

Weight variable	Mean	Standard deviation	5th percentile	25th percentile	Median	75th percentile	95th percentile	Range (maximum-minimum)
Original weight	37,788	34,546	3,414	8,327	26,229	61,058	105,916	260,381
Adjusted NHANES weight								
Birth rates in 5-year age groups	2,229	2,961	17	266	918	2,939	8,763	30,163
Birth rates in 5-year age groups and four race and ethnicity groups[1]	2,230	2,815	18	407	913	3,168	8,384	35,862
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[2]	2,317	3,349	13	309	899	2,500	10,059	34,328
Birth rates in single-year age groups	2,231	3,001	14	231	861	2,937	8,768	29,493
Birth rates in single-year age groups and four race and ethnicity groups[1]	2,237	2,868	15	344	884	3,134	8,440	35,640
Birth rates in single-year age groups and three NHANES race and ethnicity domains[2]	2,321	3,402	13	258	828	2,558	10,166	34,138

[1]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.

[2]Mexican American, non-Hispanic black, and non-Hispanic white/other.

NOTE: NHANES is National Health and Nutrition Examination Survey.

Table 4. Correlations among original and adjusted weight variables (unweighted statistics) for women aged 16–49: National Health and Nutrition Examination Survey, 1999–2008

Weight variable	Original weight	Adjusted weight 1	Adjusted weight 2	Adjusted weight 3	Adjusted weight 4	Adjusted weight 5	Adjusted weight 6
Original weight	1.000	0.621	0.586	0.631	0.612	0.576	0.621
Adjusted NHANES weights							
Birth rates in 5-year age groups (Adjusted weight 1)	0.621	1.000	0.978	0.984	0.985	0.960	0.966
Birth rates in 5-year age groups and four race and ethnicity groups[1] (Adjusted weight 2)	0.586	0.978	1.000	0.977	0.965	0.983	0.961
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[2] (Adjusted weight 3)	0.631	0.984	0.977	1.000	0.969	0.960	0.983
Birth rates in single-year age groups (Adjusted weight 4)	0.612	0.985	0.965	0.969	1.000	0.976	0.982
Birth rates in single-year age groups and four race and ethnicity groups[1] (Adjusted weight 5)	0.576	0.960	0.983	0.960	0.976	1.000	0.977
Birth rates in single-year age groups and three NHANES race and ethnicity domains[2] (Adjusted weight 6)	0.621	0.966	0.961	0.983	0.982	0.977	1.000

[1]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.

[2]Mexican American, non-Hispanic black, and non-Hispanic white/other.

NOTE: NHANES is National Health and Nutrition Examination Survey.

Table 5. Geometric mean and standard error for environmental variables using different adjustment methods for women aged 16–49: National Health and Nutrition Examination Survey, 1999–2008

Method	Mercury (µg/L)		Lead (µg/dL)		PCB[1] (ng/g lipid)	
	Geometric mean	Geometric standard error	Geometric mean	Geometric standard error	Geometric mean	Geometric standard error
Original weight	0.87	0.03	0.96	0.01	46.5	1.8
Adjusted NHANES weights						
Birth rates in 5-year age groups	0.80	0.03	0.87	0.01	33.7	1.5
Birth rates in 5-year age groups and four race and ethnicity groups[2]	0.81	0.03	0.88	0.01	32.8	1.3
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	0.81	0.03	0.87	0.01	34.0	1.5
Birth rates in single-year age groups	0.81	0.03	0.87	0.01	33.5	1.5
Birth rates in single-year age groups and four race and ethnicity groups[2]	0.81	0.02	0.88	0.01	32.5	1.4
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	0.81	0.03	0.86	0.01	33.7	1.5
Direct adjustment						
Four age groups[4]	0.80	0.02	0.88	0.01	34.5	1.4
Seven age groups[5]	0.80	0.02	0.87	0.01	33.8	1.4

[1]Polychlorinated biphenyl (PCB) calculated for one-third sample for 2001–2004.
[2]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.
[3]Mexican American, non-Hispanic black, and non-Hispanic white/other.
[4]Under age 20, 20–29, 30–39, and 40–49.
[5]16–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49.

NOTES: µg/L is micrograms per liter, µg/dL is micrograms per deciliter, and ng/g lipid is nanograms per gram lipid. NHANES is National Health and Nutrition Examination Survey.

Table 6. Mean (or geometric mean) and standard error for nutritional variables using different adjustment methods for women aged 16–49: National Health and Nutrition Examination Survey, 1999–2008

Method	Folate (ng/mL)		Vitamin D[1] (ng/mL)		Body mass index (kg/m^2)		Calcium (mg/dL)		Iron (µg/dL)	
	Geometric mean	Geometric standard error	Mean	Standard error	Geometric mean	Geometric standard error	Mean	Standard error	Geometric mean	Geometric standard error
Original weight	38.5	0.4	23.8	0.4	26.8	0.1	9.38	0.01	71.9	0.5
Adjusted NHANES weights										
Birth rates in 5-year age groups	38.4	0.5	24.3	0.4	26.4	0.1	9.38	0.01	73.2	0.7
Birth rates in 5-year age groups and four race and ethnicity groups[2]	38.1	0.4	23.7	0.4	26.5	0.1	9.38	0.01	72.7	0.7
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	38.7	0.5	24.9	0.4	26.3	0.1	9.38	0.01	74.1	0.7
Birth rates in single-year age groups	38.4	0.5	24.3	0.4	26.5	0.1	9.38	0.01	73.2	0.7
Birth rates in single-year age groups and four race and ethnicity groups[2]	38.1	0.4	23.7	0.4	26.5	0.1	9.38	0.01	72.7	0.7
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	38.8	0.5	25.0	0.4	26.3	0.1	9.38	0.01	74.1	0.7
Direct adjustment										
Four age groups[4]	38.2	0.4	24.3	0.4	26.4	0.1	9.39	0.01	73.2	0.7
Seven age groups[5]	38.4	0.5	24.3	0.4	26.4	0.1	9.39	0.01	73.2	0.7

[1]Calculated for 2001–2006.

[2]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.

[3]Mexican American, non-Hispanic black, and non-Hispanic white/other.

[4]Under age 20, 20–29, 30–39, and 40–49.

[5]16–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49.

NOTES: ng/mL is nanograms per milliliter, kg/m^2 is kilograms per meter^2, mg/dL is milligrams per deciliter, and µg/dL is micrograms per deciliter. NHANES is National Health and Nutrition Examination Survey.

Table 7. Percentiles (95% confidence intervals) for environmental variables using different weight methods for women aged 16–49: National Health and Nutrition Examination Survey, 1999–2008

Percentile and method	Mercury (µg/L) Percentile	Mercury (µg/L) Lower	Mercury (µg/L) Upper	Lead (µg/dL) Percentile	Lead (µg/dL) Lower	Lead (µg/dL) Upper	PCB[1] (ng/g lipid) Percentile	PCB[1] (ng/g lipid) Lower	PCB[1] (ng/g lipid) Upper
95th percentile									
Original weight	5.2	4.7	5.8	2.6	2.4	2.7	194.2	182.2	208.6
Adjusted NHANES weights:									
Birth rates in 5-year age groups	4.9	4.2	5.6	2.3	2.1	2.4	109.0	103.7	147.9
Birth rates in 5-year age groups and four race and ethnicity groups[2]	4.9	4.2	5.6	2.4	2.2	2.5	109.0	102.8	147.9
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	5.0	4.2	5.8	2.3	2.1	2.4	109.0	102.8	147.9
Birth rates in single-year age groups	4.9	4.2	5.6	2.3	2.1	2.4	108.7	102.8	145.3
Birth rates in single-year age groups and four race and ethnicity groups[2]	4.9	4.1	5.6	2.3	2.2	2.5	108.7	101.7	128.7
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	5.0	4.2	5.8	2.2	2.1	2.4	108.7	101.8	147.9
85th percentile									
Original weight	2.6	2.3	2.9	1.7	1.7	1.8	115.9	103.8	128.7
Adjusted NHANES weights:									
Birth rates in 5-year age groups	2.4	2.2	2.7	1.5	1.5	1.6	77.0	67.6	88.9
Birth rates in 5-year age groups and four race and ethnicity groups[2]	2.4	2.2	2.7	1.6	1.5	1.6	76.7	67.3	87.6
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	2.5	2.2	2.8	1.5	1.5	1.6	77.0	67.4	92.2
Birth rates in single-year age groups	2.4	2.2	2.7	1.5	1.5	1.6	77.0	67.6	87.6
Birth rates in single-year age groups and four race and ethnicity groups[2]	2.4	2.2	2.7	1.5	1.5	1.6	76.4	66.2	85.5
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	2.5	2.2	2.7	1.5	1.5	1.6	77.0	66.9	88.7

[1]Polychlorinated biphenyl (PCB) calculated for one-third sample for 2001–2004.

[2]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.

[3]Mexican American, non-Hispanic black, and non-Hispanic white/other.

NOTES: µg/L is micrograms per liter, µg/dL is micrograms per deciliter, and ng/g lipid is nanograms per gram lipid. NHANES is National Health and Nutrition Examination Survey.

Table 8. Percentiles (95% confidence intervals) for nutritional variables using different weight methods for women aged 16–49: National Health and Nutrition Examination Survey, 1999–2008

Percentile and method	Folate (ng/mL)			Vitamin D[1] (ng/mL)			Body mass index (kg/m²)			Calcium (mg/dL)			Iron (µg/dL)		
	Percentile	Lower	Upper	Percentile	Lower	Upper	Percentile	Lower	Upper	Percentile	Lower	Upper	Percentile	Lower	Upper
95th percentile															
Original weight	80.7	78.0	83.8	47	45	49	41.6	40.9	42.4	10.0	10.0	10.0	153	150	158
Adjusted NHANES weights:															
Birth rates in 5-year age groups	79.3	76.6	83.7	48	46	51	41.2	40.1	42.0	10.0	9.9	10.0	159	153	162
Birth rates in 5-year age groups and four race and ethnicity groups[2]	79.1	75.9	83.3	47	45	50	41.2	40.0	41.8	10.0	9.9	10.0	158	152	161
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	80.8	76.8	85.1	49	46	51	40.8	39.6	41.6	10.0	9.9	10.0	159	154	163
Birth rates in single-year age groups	80.0	76.6	83.8	49	46	51	41.3	40.3	42.2	10.0	9.9	10.0	159	153	162
Birth rates in single-year age groups and four race and ethnicity groups[2]	79.1	75.9	83.5	47	45	50	41.3	40.2	42.0	10.0	9.9	10.0	158	152	161
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	80.9	76.8	85.2	49	46	51	40.9	39.7	41.7	10.0	9.9	10.0	160	154	163
85th percentile															
Original weight	61.8	60.8	63.0	38	37	39	35.2	34.7	35.7	9.8	9.7	9.8	124	121	126
Adjusted NHANES weights:															
Birth rates in 5-year age groups	61.5	60.2	62.8	40	38	42	34.6	34.0	35.1	9.8	9.7	9.8	126	124	129
Birth rates in 5-year age groups and four race and ethnicity groups[2]	61.2	59.9	62.2	39	38	41	34.7	34.1	35.1	9.7	9.7	9.8	126	123	128
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	62.0	60.8	63.1	40	39	42	34.4	33.7	35.0	9.8	9.7	9.8	128	125	130
Birth rates in single-year age groups	61.8	60.2	62.8	40	38	42	34.8	34.1	35.3	9.7	9.7	9.8	126	124	129
Birth rates in single-year age groups and four race and ethnicity groups[2]	61.2	59.9	62.2	39	38	41	34.8	34.2	35.3	9.7	9.7	9.8	125	123	128
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	62.0	60.8	63.3	40	39	42	34.5	33.8	35.0	9.7	9.7	9.8	127	124	130

[1]Calculated for 2001–2006.

[2]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.

[3]Mexican American, non-Hispanic black, and non-Hispanic white/other.

NOTES: ng/mL is nanograms per milliliter, kg/m² is kilograms per meter², mg/dL is milligrams per deciliter, and µg/dL is micrograms per deciliter. NHANES is National Health and Nutrition Examination Survey.

Table 9. Mean and standard deviation for environmental variables using different adjustment methods for women aged 16–49, by race and ethnicity: National Health and Nutrition Examination Survey, 1999–2008

Race and ethnicity and method	Mercury (µg/L)		Lead (µg/dL)		PCB[1] (ng/g lipid)	
	Geometric mean	Geometric standard error	Geometric mean	Geometric standard error	Geometric mean	Geometric standard error
Non-Hispanic white/All other groups						
Original weight	0.87	0.03	0.93	0.01	48.8	2.3
Adjusted NHANES weights:						
Birth rates in 5-year age groups	0.81	0.03	0.84	0.01	35.7	2.0
Birth rates in 5-year age groups and four race and ethnicity groups[2]	0.84	0.03	0.85	0.01	36.8	2.1
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	0.82	0.03	0.84	0.01	36.7	2.1
Birth rates in single-year age groups	0.81	0.03	0.83	0.01	35.4	2.0
Birth rates in single-year age groups and four race and ethnicity groups[2]	0.83	0.03	0.85	0.01	36.4	2.1
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	0.82	0.03	0.84	0.01	36.3	2.1
Direct adjustment:						
Four age groups[4]	0.80	0.03	0.84	0.01	36.2	1.8
Seven age groups[5]	0.80	0.03	0.83	0.01	35.2	1.8
Non-Hispanic black						
Original weight	1.04	0.05	1.09	0.03	53.8	3.0
Adjusted NHANES weights:						
Birth rates in 5-year age groups	0.93	0.04	0.95	0.03	36.4	2.6
Birth rates in 5-year age groups and four race and ethnicity groups[2]	0.88	0.04	0.92	0.03	33.4	2.2
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	0.89	0.04	0.92	0.03	33.2	2.2
Birth rates in single-year age groups	0.94	0.04	0.94	0.03	37.0	2.7
Birth rates in single-year age groups and four race and ethnicity groups[2]	0.89	0.04	0.92	0.03	33.8	2.4
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	0.89	0.04	0.92	0.03	33.7	2.4
Direct adjustment:						
Four age groups[4]	0.94	0.04	0.96	0.03	38.5	2.3
Seven age groups[5]	0.93	0.04	0.95	0.03	38.1	2.3
Mexican American						
Original weight	0.69	0.03	1.09	0.03	25.7	1.3
Adjusted NHANES weights:						
Birth rates in 5-year age groups	0.65	0.03	1.03	0.03	20.1	1.3
Birth rates in 5-year age groups and four race and ethnicity groups[2]	0.64	0.03	1.01	0.03	19.3	1.2
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	0.63	0.03	1.01	0.03	19.1	1.2
Birth rates in single-year age groups	0.65	0.03	1.02	0.03	19.9	1.3
Birth rates in single-year age groups and four race and ethnicity groups[2]	0.64	0.03	1.01	0.03	19.1	1.2
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	0.63	0.03	1.01	0.03	19.0	1.2
Direct adjustment:						
Four age groups[4]	0.65	0.03	1.04	0.03	21.5	1.1
Seven age groups[5]	0.66	0.03	1.03	0.03	20.9	1.0

[1]Polychlorinated biphenyl (PCB) calculated for one-third sample for 2001–2004.

[2]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.

[3]Mexican American, non-Hispanic black, and non-Hispanic white/other.

[4]Under age 20, 20–29, 30–39, and 40–49.

[5]16–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49.

NOTES: µg/L is micrograms per liter, µg/dL is micrograms per deciliter, and ng/g lipid is nanograms per gram lipid. NHANES is National Health and Nutrition Examination Survey.

Table 10. Mean (or geometric mean) and standard deviation for nutritional variables using different adjustment methods for women aged 16–49, by race and ethnicity: National Health and Nutrition Examination Survey, 1999–2008

Race and ethnicity and method	Folate (ng/mL)		Vitamin D[1] (ng/mL)		Body mass index (kg/m²)		Calcium (mg/dL)		Iron (µg/dL)	
	Geometric mean	Geometric standard error	Mean	Standard error	Geometric mean	Geometric standard error	Mean	Standard error	Geometric mean	Geometric standard error
Non-Hispanic white/All other groups										
Original weight	12.9	0.2	26.2	0.4	26.2	0.2	9.39	0.01	75.0	0.7
Adjusted NHANES weights:										
Birth rates in 5-year age groups	12.9	0.2	27.0	0.5	25.8	0.2	9.40	0.01	76.6	0.9
Birth rates in 5-year age groups and four race and ethnicity groups[2]	12.9	0.2	26.7	0.4	25.9	0.2	9.39	0.01	76.6	0.9
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	12.9	0.2	27.0	0.4	25.9	0.2	9.39	0.01	76.7	0.9
Birth rates in single-year age groups	12.9	0.2	27.0	0.5	25.8	0.2	9.39	0.01	76.7	0.9
Birth rates in single-year age groups and four race and ethnicity groups[2]	12.9	0.2	26.8	0.5	25.9	0.2	9.39	0.01	76.6	0.9
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	12.9	0.2	27.0	0.5	25.9	0.2	9.39	0.01	76.6	0.9
Direct adjustment:										
Four age groups[4]	12.9	0.2	26.9	0.5	25.8	0.2	9.40	0.01	76.6	0.9
Seven age groups[5]	12.9	0.2	27.0	0.4	25.8	0.2	9.40	0.01	76.7	0.9
Non-Hispanic black										
Original weight	10.4	0.2	13.5	0.3	29.6	0.2	9.40	0.01	60.0	0.7
Adjusted NHANES weights:										
Birth rates in 5-year age groups	10.3	0.2	13.6	0.3	29.3	0.2	9.39	0.02	60.8	0.8
Birth rates in 5-year age groups and four race and ethnicity groups[2]	10.2	0.2	13.6	0.3	28.9	0.2	9.40	0.02	61.1	0.8
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	10.2	0.2	13.5	0.3	28.8	0.2	9.40	0.02	61.2	0.8
Birth rates in single-year age groups	10.3	0.2	13.5	0.3	29.3	0.2	9.39	0.02	60.8	0.8
Birth rates in single-year age groups and four race and ethnicity groups[2]	10.2	0.2	13.5	0.3	28.9	0.2	9.40	0.02	61.2	0.8
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	10.2	0.2	13.5	0.4	28.9	0.2	9.40	0.02	61.3	0.8
Direct adjustment:										
Four age groups[4]	10.3	0.2	13.6	0.3	29.2	0.2	9.39	0.01	60.7	0.8
Seven age groups[5]	10.3	0.2	13.6	0.3	29.3	0.2	9.39	0.01	60.7	0.8
Mexican American										
Original weight	11.5	0.2	19.0	0.5	27.8	0.2	9.30	0.01	65.2	1.1
Adjusted NHANES weights:										
Birth rates in 5-year age groups	11.5	0.3	19.6	0.5	27.5	0.2	9.30	0.01	66.7	1.2
Birth rates in 5-year age groups and four race and ethnicity groups[2]	11.5	0.2	19.6	0.5	27.2	0.2	9.31	0.01	66.7	1.3
Birth rates in 5-year age groups and three NHANES race and ethnicity domains[3]	11.4	0.2	19.6	0.5	27.2	0.2	9.31	0.01	66.7	1.3
Birth rates in single-year age groups	11.5	0.3	19.6	0.5	27.6	0.2	9.30	0.01	66.8	1.2
Birth rates in single-year age groups and four race and ethnicity groups[2]	11.5	0.2	19.5	0.5	27.2	0.2	9.31	0.01	66.8	1.3
Birth rates in single-year age groups and three NHANES race and ethnicity domains[3]	11.4	0.3	19.6	0.5	27.2	0.2	9.31	0.01	66.9	1.3
Direct adjustment:										
Four age groups[4]	11.4	0.2	19.5	0.5	27.5	0.2	9.31	0.01	66.4	1.3
Seven age groups[5]	11.5	0.3	19.5	0.5	27.6	0.2	9.30	0.01	66.6	1.2

[1]Calculated for 2001–2006.

[2]Mexican American, non-Hispanic black, non-Hispanic white, and all other races and ethnicities.

[3]Mexican American, non-Hispanic black, and non-Hispanic white/other.

[4]Under age 20, 20–29, 30–39, and 40–49.

[5]16–19, 20–24, 25–29, 30–34, 35–39, 40–44, and 45–49.

NOTES: ng/mL is nanograms per milliliter, kg/m² is kilograms per meter², mg/dL is milligrams per deciliter, and µg/dL is micrograms per deciliter. NHANES is National Health and Nutrition Examination Survey.

Appendix I. Calculation of Polychlorinated Biphenyls

Blood serum levels of polychlorinated biphenyls (PCBs) were analyzed in women of childbearing age. There are 209 possible PCBs, referred to as ''congeners,'' which are defined by the number of chlorine atoms (from one to 10) and their position in the chemical structure. PCBs are lipophilic, meaning that they tend to accumulate in fat. Serum PCB concentrations are measured and expressed on a lipid-adjusted basis, because these values better represent the amount of PCBs stored in the body compared with unadjusted values. The lipid-adjusted concentration is the concentration of PCBs in serum divided by the concentration of lipid in serum. The resulting units are nanograms of PCB per gram of lipid (ng/g lipid) in serum.

This analysis uses the sum of four specific congeners measured in the National Health and Nutrition Examination Survey (NHANES): PCBs 118, 138, 153, and 180. The full chemical names are: 2,3',4,4',5-pentachlorophenyl; 2,2',3,4,4',5- and 2,3,3',4,4',6-hexachlorophenyl; 2,2',4,4',5,5'- hexachlorophenyl; and 2,2',3,4,4',5,5'-heptachlorophenyl, respectively. These four congeners are generally found at higher levels in the environment—and in human blood samples—than other PCB congeners. This combination of congeners has been used to represent PCB exposure in epidemiological studies (15). If a congener was measured but not detected in a sample, a default value of the detection limit divided by the square root of two was assigned for purposes of calculating the summed total. If some but not all of the four PCB congeners are missing, then the sum is above the nonmissing PCB congeners.

For these analyses, serum PCB data for the 1999–2000 cycle were not used because the four congeners of interest were much more frequently below the detection limit (approximately 80% of measurements); serum PCB data after 2004 were not available at the time of this report. Thus, the analyses of serum PCBs use a much narrower range of years than the other environmental and nutritional variables studied here. Furthermore, the PCB congeners were measured in a one-third sample of the NHANES data, which further reduces the available sample size. Despite the smaller number of measurements, serum PCBs are included in these analyses because the Axelrad and Cohen analyses showed relatively large effects of the natality adjustment for this variable compared with blood mercury and serum cotinine (9).

Appendix II. Means or Geometric Means for Variables, by Age Group

Table. Means or geometric means for variables for women aged 16–49, by age group: National Health and Nutrition Examination Survey, 1999–2008

Age group (years)	Mercury (µg/L)		Lead (µg/dL)		PCB (ng/g lipid)		Folate (ng/mL)	
	Geometric mean	Geometric SE	Geometric mean	Geometric SE	Geometric mean	Geometric SE	Geometric mean	Geometric SE
16–19	0.55	0.02	0.71	0.01	19.61	0.79	38.12	0.64
20–24	0.71	0.03	0.83	0.02	26.72	1.57	37.56	0.74
25–29	0.79	0.04	0.84	0.02	29.77	2.15	38.65	0.84
30–34	0.99	0.05	0.93	0.02	42.79	3.13	39.59	0.90
35–39	0.98	0.06	1.02	0.03	62.56	4.72	37.37	0.83
40–44	1.00	0.04	1.11	0.02	80.21	5.35	38.11	0.79
45–49	1.10	0.05	1.28	0.03	97.35	4.52	40.09	1.01

Age group (years)	Vitamin D (ng/mL)		Body mass index (kg/m^2)		Calcium (mg/dL)		Iron (µg/dL)	
	Mean	SE	Geometric mean	Geometric SE	Mean	SE	Geometric mean	Geometric SE
16–19	24.17	0.61	23.77	0.15	9.54	0.02	72.49	1.29
20–24	24.21	0.76	25.84	0.25	9.41	0.01	73.48	1.48
25–29	24.61	0.64	26.67	0.26	9.36	0.02	73.41	1.55
30–34	24.36	0.53	27.32	0.26	9.35	0.02	73.87	1.59
35–39	23.95	0.68	27.41	0.29	9.35	0.02	72.65	1.63
40–44	22.68	0.56	27.80	0.28	9.34	0.02	67.59	1.42
45–49	22.96	0.45	28.21	0.30	9.40	0.02	70.73	1.44

NOTES: µg/L is micrograms per liter, µg/dL is micrograms per deciliter, ng/g lipid is nanograms per gram lipid, ng/mL is nanograms per milliliter, kg/m^2 is kilograms per $meter^2$, and mg/dL is milligrams per deciliter. PCB is polychlorinated biphenyl. SE is standard error.

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