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National Health and Nutrition Examination Survey: Analytic Guidelines, 1999–2010

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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

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Abstract

Background

Analytic guidelines were first created in 1996 to assist data users in analyzing data from the Third National Health and Nutrition Examination Survey (NHANES III), conducted from 1988 to 1994 by the Centers for Disease Control and Prevention's National Center for Health Statistics. NHANES became a continuous annual survey in 1999, with data released to the public in 2-year intervals. In 2002, 2004, and 2006, guidelines were created and posted on the NHANES website to assist analysts in understanding the key issues related to analyzing data from 1999 onward. This report builds on these previous guidelines and provides the first comprehensive summary of analytic guidelines for the 1999–2010 NHANES data.

Objectives

This report provides general guidelines for researchers in analyzing 1999–2010 NHANES publicly released data. Information is presented on key issues related to NHANES data, including sample design, demographic variables, and combining survey cycles. Guidance is also provided on data analysis, including the use of appropriate survey weights, calculating variance estimations, determining the reliability of estimates, age adjustment, and computing population counts.

Keywords: sample design • sample weighting • estimation procedures

National Health and Nutrition Examination Survey: Analytic Guidelines, 1999–2010

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Introduction

This report presents general analytic and reporting guidelines that can be used for analyses of 1999–2010 National Health and Nutrition Examination Survey (NHANES) publicly released data. It reflects the latest knowledge of analytic issues related to the ongoing NHANES, which is conducted by the Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics (NCHS). The report is intended as a broad overview of the statistical and methodological issues the user needs to be aware of when analyzing data from a complex, continuous survey like NHANES. It does not present details on the statistical theory behind the guidelines.

Analytic guidelines were first created in 1996 for NHANES III (1). An addendum to these original guidelines was created in 2002 to reflect changes that occurred when NHANES became a continuous survey in 1999. Updated versions of the 2002 guidelines were created in 2004 and 2006. Many of the concepts and guidelines presented in these earlier versions remain in the present version, with some guidelines added and some older guidelines modified.

Note that the statistical guidelines in this document are not standards. Depending on subject matter and statistical efficiency, specific analyses may depart from these guidelines. In conducting analyses, the analyst needs to use his or her subject matter knowledge (including knowledge of methodological issues), as well as information about the survey design. The more an analyst deviates from the original analytic categories defined in the sample design, the more important it is to evaluate the results carefully and interpret the findings cautiously.

The recommended approach for analysis of NHANES data is design-based analysis. Design-based analytic procedures explicitly take into account features of the survey design, such as differential selection probabilities and geographic clustering. An important resource for all analysts is the NHANES Tutorials (2)—a Web-based product designed to assist users in understanding and analyzing NHANES data. The Continuous NHANES Tutorial provides details on analyzing data from the 1999–2010 NHANES.

Data Considerations

Sample Design

NHANES is a nationally representative survey of the resident civilian noninstitutionalized U.S. population. It consists of questionnaires administered in the home, followed by a standardized physical examination in a specially equipped mobile examination center (MEC). The examination includes physical measurements such as blood pressure, a dental examination, and the collection of blood and urine specimens for laboratory testing.

NHANES data are not obtained using a simple random sample. Rather, a complex, multistage probability sampling design is used to select a sample representative of the civilian noninstitutionalized resident population of the United States. NHANES excludes all persons in supervised care or custody in institutional settings, all active-duty military personnel, active-duty family members living overseas, and any other U.S. citizens residing outside the 50 states and the District of Columbia. Noninstitutional group quarters are included in the survey [refer to the glossary (Appendix) for details on noninstitutional and institutional group quarters].

NHANES uses a four-stage sampling design: first, selection of the primary sampling units (PSUs) (i.e., mostly individual counties); second, selection of segments within the counties; third, selection of dwelling units (DUs) or households within segments; and fourth, selection of individuals within a household. Since 1999, the annual sample size has been approximately 5,000 individuals from 15 different locations (12 locations for 1999) selected from a sampling frame that includes all 50 states and the District of Columbia. Refer to the NHANES Sample Design Reports (3,4) for further details.

Design changes related to race and Hispanic origin

NHANES is designed to sample larger numbers of certain subgroups of particular public health interest. Oversampling is done to increase the reliability and precision of estimates of health status indicators for these population subgroups. Weighting schemes allow estimates from these subgroups to be combined to obtain a national estimate that reflects the relative proportions of these groups in the population as a whole.

Table A. Recommended Hispanic subgroups for analyses: National Health and Nutrition Examination Survey, 1999–2010

Subgroup	Survey years		
	1999–2006	2007–2010	1999–2010[1]
Mexican-American	Yes	Yes	Yes
Non-Mexican-American Hispanic	No	No	No
All Hispanic	No	Yes	No

[1]Recommended subgroups for 1999–2010 and when combining any survey years from 1999–2006 and 2007–2010.

NHANES has oversampled the following subgroups:

1999–2006

- Mexican-American persons.
- Black persons.
- White and Other persons at or below 130% of the federal poverty level (beginning in 2000).
- White and Other persons aged 70 and over.
- Adolescents aged 12–19.

2007–2010

- Hispanic persons.
- Non-Hispanic black persons.
- Non-Hispanic white and Other persons at or below 130% of the federal poverty level.
- Non-Hispanic white and Other persons aged 80 and over.

During 1999–2006, a supplemental sample of pregnant women was also included (see the later ‘‘Subsample weights’’ section).

For the 1999–2006 survey periods, the proportion of non-Mexican-American Hispanic persons in the NHANES sample was much smaller than in the U.S. population and is generally considered to be too small to produce reliable estimates. For the 2007–2010 survey periods, all Hispanic persons were oversampled, rather than just Mexican-American Hispanic persons. So, in addition to allowing estimates for the total group of Hispanic persons, the sample size for Mexican-American persons is sufficient to continue to produce reliable estimates for this group. However, the methodology for the oversampling of Hispanic persons did not provide sufficient sample sizes for calculating estimates for other Hispanic subgroups besides Mexican-American persons.

NCHS strongly recommends that researchers not calculate estimates for all Hispanic persons for survey periods prior to 2007, or for non-Mexican-American Hispanic subgroups in any survey cycle during 1999–2010.

Table A summarizes the recommendations for appropriate Hispanic subgroup analyses from NHANES 1999–2010.

Survey subsamples

NHANES respondents are asked to participate in a variety of survey components that are either statistically defined or random subsamples of the NHANES interviewed or examined sample. These include laboratory, nutrition and dietary, environmental, and mental health components. For example, some but not all participants are selected to give a fasting blood sample on the morning of their MEC examination. The subsamples selected for these components are chosen at random with a specified sampling fraction (e.g., one-half or one-third of the total examined group), according to the protocol for that component. Each component subsample usually has its own designated weight, which accounts for the additional probability of selection into the subsample component as well as the additional nonresponse. The subsections that follow provide information on the specific survey subsamples from NHANES 1999–2010. Detail on the subsample weights is provided later, in the ‘‘Subsample weights’’ section.

Supplemental sample of pregnant women, NHANES 1999–2006

Pregnancy status was ascertained for females aged 8–59 (see the ‘‘Subsetting data’’ section for further details on pregnancy status). To improve the precision of estimates for pregnant women, a supplemental sample of pregnant women was selected. Only women aged 15–39 were eligible for this sample. The NHANES 1999–2006 Sample Design report (3) gives further details on how pregnant women were sampled.

Because of sample design changes for 2007–2010, pregnant women aged 15–39 and individuals 12–19 were no longer oversampled. This change reduced the number of pregnant women sampled during 2007–2010. This supplemental sample does not require a special sample weight because it was accounted for in creating the basic survey sample weights.

Fasting subsample

NHANES had two subsamples in each examination session: the morning subsample, and the afternoon or evening subsample. Because sample participants selected for the morning sessions were instructed to fast overnight, data sensitive to fasting times should be analyzed separately for these two groups. Refer to the NHANES 1999–2006 Sample Design report (3) for further details.

Examination and laboratory subsamples

The examination component of NHANES consisted of medical, dental, and physiological measurements, as well as numerous laboratory tests to assess various aspects of health. For some of these components, subsampling was required in order to reduce respondent burden and facilitate the scheduling and completion of examinations. Refer to the respective survey protocol and documentation for more specific information.

Examples of subsamples include environmental chemical analytes (e.g., volatile organic compounds, perchlorate, and heavy metals) and examination components such as hearing (2003–2004 only) and the Composite International Diagnostics (2003–2004 only). Refer to the NHANES Sample Design reports (3,4) for further details on the specific subsamples. Component documentation on the NHANES website at http://www.cdc.gov/nhanes gives information on analyzing the subsamples.

Geographical considerations

Starting in 1999, NHANES began interviewing and examining a nationally representative sample of approximately 5,000 persons each year. These persons are located in counties across the country. During a single survey year, about 15 counties are selected out of approximately 3,000 counties in the United States. No geographic location, including true PSUs, is released on the publicly available data files, to protect the identity of NHANES respondents.

To answer important research questions about the effect of geography on health, and to analyze a finer level of geographic detail with the NHANES data, NCHS has asked the U.S. Department of Housing and Urban Development (HUD) to geocode (assign geographic codes to) NHANES data for analytical use in every 2-year cycle. HUD geocoded the 1999–2010 NHANES data to U.S. Census Bureau data and provided the following information:

- Census block group, census tract, county, state, and all other census codes normally provided by the HUD Geocoding Service Center (http://egis.hud.gov/) for each residential address.
- Latitude and longitude for each residential address.

These data may be obtained through the NCHS Research Data Center (RDC), along with other variables such as true PSUs and strata that may be necessary for these types of analyses. Refer to geocoding documentation on the NHANES website (at http://www.cdc.gov/nchs/nhanes/limited_access/N0910_GE.htm) for further details on these data. The RDC allows for both remote and onsite access, but a formal application must be completed. All submitted analyses are subject to disclosure review. For more information on using the RDC, see http://www.cdc.gov/rdc/.

NHANES 1999–2010 was not designed to produce regional or subregional estimates. However, state- and county-level information is available through the RDC and researchers have produced local-level estimates for Los Angeles (5) and for California overall. Other subregional estimates may be challenging to produce and would require creation of sample weights that are not provided by NCHS.

Seasonality

MEC operational considerations make it necessary to avoid certain geographic areas during the winter. Thus, the statistical efficiency of the sample is diminished for any variable that may be related to seasonal variation that differs by region of the country (for example, certain nutrition or environmental exposure variables). In particular, consumption of certain foods may be subject to the seasonality-by-geography interaction.

Most NHANES variables are not subject to seasonality constraints. The variable RIDEXMON, in the public-release Demographic File, provides the 6-month period when the examination was performed and is categorized into two groups: November 1 through April 30 and May 1 through October 31.

Key Demographic Variables of Interest

Age

Appropriate age variable for analysis

Three age variables are released with the public data files:

- RIDAGEYR, age in years at screening—Records the best age in years of the sample person at the time of the initial household screening interview (or ‘‘screener’’).
- RIDAGEMN, age in months at screener—Records the best age in months at date of screener.
- RIDAGEEX, age in months at examination—Records the best age in months at date of examination.

For survey years 1999–2006, individuals aged 85 and over were top-coded at age 85; for 2007–2010, those aged 80 and over were top-coded at 80.

Each respondent's actual or imputed date of birth was used to calculate RIDAGEYR. NCHS uses the following procedure to impute age at the screener when the date of birth is missing or refused but the respondent's age in years is provided:

- If month of birth is missing or not given, it is imputed as 7.
- If day of birth is missing or not given, it is imputed as 1.
- If year of birth is missing or not given, it is imputed as the year of the screener minus the age in years provided by the respondent during the interview.

Age at screening was used to determine eligibility for an examination component. RIDAGEYR should be used for most analyses. However, age in months may be more appropriate for certain analyses. For example, when analyzing anthropometric data on children and youths from birth through age 19, RIDAGEEX would be used.

Demographic File documentation (available from: http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm) provides further details on these age variables.

Defining age group categories

Age groups used in an analysis should be based on what is most appropriate for the specific analysis, in conjunction with established statistical reliability criteria. Although single year of age is provided on the publicly released data files, the sample sizes for such a detailed age classification are too small, and some form of age grouping is required. When possible, the age grouping should be consistent with the survey design groupings detailed in the NHANES Sample Design reports (3,4).

The following age categories are recommended for most 2-year analyses and are generally consistent with the NHANES 1999–2010 sample design age groups:

- Under 1 year to 5 years
- 6–11
- 12–19
- 20–39
- 40–59
- 60 and over

Other age groups may be used, but refer to the Sample Design reports (3,4) for their appropriateness.

If age groups other than those consistent with the sample design are needed for an analysis, collapsing of age groups or combining of survey years may be necessary. For example, in a 2-year data set, there are not enough Mexican-American men and women aged 70 and over to present findings for this age group with confidence. Consequently, the age group 70 and over must be collapsed with the group 60–69, or both sexes must be combined for ages 70 and over, or additional survey years must be combined.

Some questionnaire items and some examinations are done on a limited age range that may not correspond exactly with the sample design age groups. For example, the Early Childhood Questionnaire ends at age 15. This is another example of why the data file documentation should be consulted before beginning any analysis.

Age group considerations when comparing 1999–2010 data with earlier years

The National Health Examination Survey (NHES) of the 1960s had various age groups. NHES I (1959–1962) included adults aged 18–79. NHES II (1963–1965) and III (1966–1970) were conducted on children aged 6–11 and 12–17, respectively. The various NHANES also included different age groups: NHANES I (1971–1974) sampled participants aged 1–74; NHANES II (1976–1980) and Hispanic HANES (1982–1984) sampled those aged 6 months to 74 years; and NHANES III (1988–1994) sampled those 2 months and over. Beginning in 1999, the age range was expanded to include all ages.

Age group or trend analysis on adults based on NHANES beginning in 1988 should categorize adults as aged 20 and over. Trend analysis involving NHES and NHANES conducted before 1988 should use ages 20–74 as the summary age group.

Race and Hispanic origin

The 1999–2004 publicly released demographic data files contain two race and ethnicity variables: RIDRETH1 and RIDRETH2. The 2005–2010 demographic files contain only RIDRETH1. Both variables were derived by combining participant responses to questions on race and Hispanic origin.

For RIDRETH1, respondents who self-identified as ''Mexican-American'' were coded as such (RIDRETH1 = 1), regardless of their other racial or ethnic identities. Otherwise, a self-identified ''Hispanic'' ethnicity would be coded ''2, Other Hispanic.'' All other non-Hispanic participants would then be categorized based on their self-reported races: non-Hispanic white (RIDRETH1 = 3), non-Hispanic black (RIDRETH1 = 4), and other non-Hispanic race including non-Hispanic multiracial (RIDRETH1 = 5). To obtain estimates for total Hispanic persons for 2007–2010, RIDRETH1 = 1 (Mexican-American) must be combined with RIDRETH1 = 2 (Other Hispanic).

RIDRETH2 is the race-ethnicity recode that can be linked to the NHANES III race-ethnicity variable. Non-Hispanic participants who indicated more than one race (multiracial) and then selected a main race as black (non-Hispanic) or white (non-Hispanic) were recoded into those respective categories. In other cases, the coding was similar to RIDRETH1. Refer to the ''Design changes related to race and Hispanic origin'' section for more detail. RIDRETH1 should be used for analyses of data for 1999–2010. To examine trends between NHANES III and NHANES 1999–2004, RIDRETH2 should be used.

Income

The 1999–2010 publicly released demographic data files contain three income variables: INDFMINC, total family income; INDHHINC, estimated total household income; and INDFMPIR, the ratio of family income to poverty.

NHANES used the Census Bureau's Current Population Survey (CPS) definition of ''family'' to group household members into one or more families. CPS defines a family as ''a group of two people or more (one of whom is the householder) related by birth, marriage, or adoption and residing together; all such people (including related subfamily members) are considered as members of one family'' (http://www.census.gov/cps/about/cpsdef.html).

The best income variable to use when comparing data over time is INDFMPIR, which is an index for the ratio of family income to poverty. The U.S. Department of Health and Human Services' poverty guidelines (http://aspe.hhs.gov/poverty/13poverty.cfm) were used to calculate this index. These guidelines are issued yearly in the Federal Register for use in determining financial eligibility for federal programs such as Head Start; Supplemental Nutrition Assistance Program (SNAP) (formerly the Food Stamp Program); Special Supplemental Nutrition Program for Women, Infants, and Children (WIC); and the National School Lunch Program.

The variable INDFMPIR was calculated by dividing family income by the poverty guidelines specific to family size, as well as the appropriate year and state. The values were not computed if the income screener information (INQ 220: less than $20,000 or greater than or equal to $20,000) was the only family income information reported. If family income was reported as a range value, the midpoint of the range was used to compute the variable. INDFMPIR values at or above 5.00 were coded as 5.00 or more because of disclosure concerns. The values were not computed if family income was missing.

The reporting categories will depend on sample size and the research question of interest. The family income-to-poverty ratio (FIPR) can be categorized as follows:

- 0.00–0.99 = Below poverty; 1.00 and above = At or above poverty.
- Based on SNAP eligibility: 0.00–1.30, >1.30–3.50, and >3.50 and above.
- Based on WIC eligibility: 0.00–1.85, >1.85–3.50, and >3.50 and above.

Pregnancy status

Pregnancy status at the time of examination (RIDEXPRG) was determined for females aged 8–59. The information used to code RIDEXPRG values included urine pregnancy test results and self-reported pregnancy status. Urine pregnancy tests were performed prior to the dual-energy x-ray absorptiometry (DXA) exam. Persons who reported they were pregnant at the time of examination were assumed to be pregnant (RIDEXPRG = 1). Those who reported they were not pregnant or did not know their pregnancy status were further classified based on the results of the urine pregnancy test. If the respondent reported ''no'' or ''don't know'' and the urine test result was positive, the respondent was coded as pregnant (RIDEXPRG = 1). If the respondent reported ''no'' and the urine test was negative, the respondent was coded not pregnant (RIDEXPRG = 2). If the respondent reported she did not know her pregnancy status and the urine test was negative, the respondent was coded ''could not be determined'' (RIDEXPRG = 3). Persons who were only interviewed were coded RIDEXPRG = 3 (pregnancy could not be determined).

During 1999–2002, a second pregnancy recode variable, RIDPREG, was publicly released. RIDPREG was created as a preliminary pregnancy status and is considered to be a more conservative indicator of pregnancy status. Refer to the Demographic File documentation for the respective years for additional details (http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm).

The variable RIDEXPRG should be used in examining trends or combining data from 1999–2002 with later survey years. As a result of sample design changes during 2007–2010 that reduced the number of pregnant women sampled, pregnancy status was publicly released only for women aged 20–44, to reduce disclosure risk.

Combining NHANES 1999–2010 Survey Cycles

Each 2-year cycle, and any combination of 2-year cycles, is considered a nationally representative sample. However, the sample size of a particular cell may be too small based on an individual 2-year cycle to produce statistically reliable estimates. Fortunately, the NHANES sample design makes it possible to combine two or more cycles to increase the sample size and analytic options. In general, any 2-year data cycle in NHANES can be combined with adjacent 2-year data cycles to create analytic data files based on 4 or more years of data, to produce estimates with greater precision and smaller sampling error.

To produce estimates with greater statistical reliability for demographic subdomains (e.g., sex-age-race and ethnicity groups) and for rare events, combining two or more 2-year cycles of the continuous NHANES is strongly recommended. When combining cycles of data, it is very important to

- Be aware of sample design changes during 2007–2010 that may affect combining the data with data from earlier years.
- Verify that data items collected in all combined years are comparable in wording, methods, and inclusions and exclusions (e.g., eligible age range).
- Select the proper weight to use for the combined data set.
- Confirm the inherent assumption of no trend in the estimate over the time periods being combined.

Refer to the ''Combining 2-year weights to analyze other multiyear samples'' section for more information on combining sample weights for analysis.

Missing Data

NHANES, like most population-based sample surveys, experiences both participant (unit) and component (item) nonresponse. In a statistical sense, nonresponse can be considered ignorable or nonignorable. If the data are missing

Table B. Overall survey response rates for all ages: National Health and Nutrition Examination Survey, 1999–2010

Survey years	Screened sample	Interviewed sample		Examined sample	
		Unweighted sample size	Unweighted response rate (percent)	Unweighted sample size	Unweighted response rate (percent)
1999–2000	12,160	9,965	82	9,282	76
2001–2002	13,156	11,039	84	10,477	80
2003–2004	12,761	10,122	79	9,643	76
2005–2006	12,862	10,348	80	9,950	77
2007–2008	12,943	10,149	78	9,762	75
2009–2010	13,272	10,537	79	10,253	77

at random and the characteristics of the nonrespondents are similar to the characteristics of the respondents, the nonresponse can be considered ignorable. However, nonrespondents may have significantly different characteristics than respondents. In this case, the nonresponse mechanism may be nonignorable with respect to the data analysis. Ignoring nonresponse in this case leads to biased estimates.

Unit or sample person nonresponse

All eligible persons selected to participate in NHANES who completed the household interview questionnaire were defined as ‘‘interviewed,’’ and all interviewed persons who completed one or more examination components in the MEC were defined as ‘‘MEC examined.’’ Not all persons in the NHANES sample were interviewed, and not all interviewed persons were examined. Unit or sample person nonresponse—the failure to obtain any information on an individual selected to participate in NHANES—can occur at both the interview and examination phases of the survey.

For example, during 2009–2010, of the 13,272 persons eligible to participate in NHANES (Table B), only 10,537 actually completed the in-home interview, for an interview nonresponse of 21%. Further, of the 10,537 sample persons interviewed, only 10,253 completed the MEC examination. Therefore, an additional 2% of the interviewed sample persons did not respond to the MEC examination. This is the MEC examination nonresponse. Both the interview and examination sample weights adjust for this level of nonresponse.

Traditionally, response rates have been used as an indicator of the likelihood of bias due to nonresponse. In general, NHANES overall response rates decrease with age. Response rates for the MEC examinations typically exceed 80% for persons under age 20; by age 70, response tends to be less than 70%. Note that any adjustments made to the sample weights for survey nonresponse account only for sample person interview or examination nonresponse, as described above, not for component or item nonresponse, which can occur at the household interview or the examination. For example, a sample person may have declined to have their blood pressure measured in the examination component but completed all other examination components; such nonresponse is described further in the next section. Overall response rates for each survey cycle are presented in Table B. Rates by age and gender are provided at: http://www.cdc.gov/nchs/nhanes/response_rates_CPS.htm.

Component or item nonresponse

In NHANES, a large number of different examinations and tests are conducted in the MEC and each component contains a number of items. Some examinees may not participate in all components of their designated examination, or may not participate fully in a particular component, resulting in component or item nonresponse. Missing values may distort analysis results. Analysts should evaluate the extent of missing data in their data set related to the outcome of interest, as well as any predictor variables used in the analyses, to determine whether the data are usable without additional reweighting for item nonresponse. As a general rule, if 10% or less of data for the main outcome variable for a specific component are missing for eligible examinees, it is usually acceptable to continue analysis without further evaluation or adjustment. However, if more than 10% of the data for a variable are missing, the analyst may need to further examine respondents and nonrespondents with respect to the main outcome variable and decide whether imputation of missing values or use of adjusted weights is necessary. Note that even if the overall component response rate is less than 10%, a subgroup within the component may exceed 10% and may need to be further examined for statistical bias.

Component nonresponse varies substantially by the demographic characteristics of the participants, the type of component, and the survey cycle. Analysts are strongly encouraged to examine component nonresponse to determine whether the survey sample weights need to be adjusted. Refer to previous publications (6–8) that address component and item nonresponse adjustment and reweighting.

Other key concepts about missing data

NHANES assigns missing values by using a period (.) for numeric variables and a blank for character variables. However, other types of data are also important to consider as unavailable for analysis and as part of the unit nonresponse for that variable. When a sample person refuses to answer a question, a ‘‘refused’’ response is assigned a value of 7, 77, or 777,

Table C. Unavailable values in data: National Health and Nutrition Examination Survey, 1999–2010

NHANES code	Description	Action
Period (.)	Missing numeric value	None
(Blank)	Missing character value	None
7, 77, or 777	"Refused" response	Code as missing (period or blank)
9, 99, or 999	"Don't know" response	Code as missing (period or blank)

depending on the number of digits in the variable value range. A ''don't know'' response is assigned a value of 9, 99, or 999, also depending on the number of digits in the variable value range (Table C).

Failure to identify these other types of missing data, and treating the assigned values for ''refused'' or ''don't know'' as real values, will distort analysis results. Therefore, it is important to recode ''refused'' or ''don't know'' responses as missing values (either a period for numeric variables or a blank for character variables).

Analytic Considerations

The most important considerations in analyzing NHANES data involve taking into account the survey design. Survey sample weights should be used, and the complex survey design must be accounted for in the estimation of variance.

Survey Sample Weights

The goal of NHANES is to produce data representative of the civilian noninstitutionalized U.S. population. The weighting of sample data permits analysts to produce estimates of the statistics they would have obtained if the entire sampling frame had been surveyed. A sample weight is assigned to each sample person. Sample weights can be considered as measures of the number of persons represented by the particular sample person. When a sample is weighted in NHANES it is considered to be representative of the U.S. civilian noninstitutionalized population.

Weighting takes into account several features of the survey: the differential probabilities of selection for the individual domains, nonresponse to survey instruments, and differences between the final sample and the total population. The sample weighting was carried out in three steps. The first step involved the computation of weights to compensate for unequal probabilities of selection, given that some groups were oversampled. The second step adjusted for participant nonresponse. Weights were adjusted for nonresponse to the in-home interview when creating the interview weights, and further adjusted for nonresponse to the MEC examination when creating the examination weights. In the third step, the sample weights were poststratified to match estimates of the U.S. noninstitutionalized population available from the Census Bureau. These steps were performed for respondents to each stage of the survey: the screener, the personal interview, and the examination.

A more detailed discussion of the sample weights can be found in ''National Health and Nutrition Examination Survey: Sample Design, 1999–2006'' (3) and ''National Health and Nutrition Examination Survey: Estimation Procedures, 2007–2010'' (9). In summary, it is important to utilize the weights in analyses to account for oversampling, survey nonresponse, and population coverage, in order to ensure that calculated estimates are representative of the U.S. civilian noninstitutionalized population.

Determining the appropriate sample weight for analysis

Various sample weights are available on the data release files. Use of the correct sample weight for NHANES analyses is extremely important and depends on the variables being used. A good general guideline is to use the ''least common denominator'' approach. With this approach, the analyst checks the variables of interest. The variable that was collected on the smallest number of persons is the least common denominator, and the sample weight that applies to that variable is the appropriate one to use for that particular analysis.

Any eligible person who did not respond to the interview was assigned an interview weight of zero (see the ''Unit or sample person nonresponse'' section). These sampled participants were considered ineligible for the examination and were also assigned an examination weight of zero. Their records were not included in the publicly released data files. Sampled participants who completed the interview and were eligible for the examination, but did not respond, were assigned a nonzero interview weight and an examination weight of zero. Their records are included in the public release. Cases with a zero examination weight should be treated as missing when the examination data are analyzed.

Subsample weights

As discussed earlier, in the ''Survey subsamples'' section, some NHANES respondents were asked to participate in survey components that were statistically defined (or random) subsamples of the NHANES MEC-examined sample. Data collected from these participants included a variety of laboratory, nutrition or dietary, environmental, audiometry, and mental health components. Each of these subsamples was selected to be a nationally representative sample. For example, some but not all participants were selected to give a fasting blood sample on the morning of their MEC examination. The subsamples selected for these components were chosen at random with a specified sampling fraction (e.g., one-half of the total examined group), according to the protocol for that component.

Each component subsample has its own designated weight, which accounts for the additional probability of selection into the subsample component, as well as any additional nonresponse to the component. For some components,

Table D. Survey sample weights and their appropriate use: National Health and Nutrition Examination Survey, 1999–2010

Weight	Application
Interview	Use when analyzing data from the home interview only. Do not use if analysis includes variables that were also collected on persons examined in the mobile examination center (MEC).
Examination	Use when analyzing data from the MEC examination. Do not use if analysis includes variables collected as part of one of the dietary interviews or as part of one of the subsamples (e.g., fasting or environmental).
Dietary day 1 sample	Use when analyzing data from the day 1 24-hour dietary recall or the Flexible Consumer Behavior Survey telephone follow-up module for examined persons who completed one or both of these interviews.
Dietary day 2 sample	Use when analyzing data from the day 1 and day 2 24-hour dietary recalls for examined persons who completed these interviews.
Fasting subsample	Use when analyzing fasting glucose, insulin levels, triglycerides, or LDL cholesterol (lipids), for examined persons assigned to and meeting the criteria for the fasting subsample.
Oral glucose tolerance test (OGTT) subsample	Use when analyzing only OGTT glucose levels, or OGTT glucose levels with other data such as insulin or fasting levels, for examined persons assigned to and meeting the criteria for the OGTT.
Volatile organic compound (VOC) subsample	Use when analyzing data from the one-half laboratory VOC subsample for examined persons assigned to and meeting the criteria for this subsample.
Laboratory subsample A	Use when analyzing data from the one-third laboratory environmental subsample A for examined persons assigned to and meeting the criteria for this subsample.
Laboratory subsample B	Use when analyzing data from the one-third laboratory environmental subsample B for examined persons assigned to and meeting the criteria for this subsample.
Laboratory subsample C	Use when analyzing data from the one-third laboratory environmental subsample C for examined persons assigned to and meeting the criteria for this subsample.
Composite international diagnostics (2003–2004)	Use when analyzing data from this one-half subsample for interviewed persons aged 20–39 assigned to and meeting the criteria for this subsample.
Hearing (2003–2004 only)	Use when analyzing data from this one-half subsample for interviewed persons aged 20–69 assigned to and meeting the criteria for this subsample.
Perchlorate (2005–2006 only)	Use when analyzing data from the one-half laboratory perchlorate subsample for examined persons aged 12 and over assigned to and meeting the criteria for this subsample.

subsample weights were calculated to incorporate additional information relevant to data collection (such as day of the week for the dietary recall data).

When data collected in one of these subsamples were released, special survey weights were constructed for that subsample and included in the data file. These weights differ from the full examination weight, and the subsample-specific weights must be used for statistical estimation of measures collected only in that subsample. (See Table D for a list of the special survey weights and for information regarding their appropriate use.)

Subsample weights from the same survey cycle are not designed to be combined within the data release cycle. In fact, many subsamples are mutually exclusive. To combine two or more subsamples, random overlap would have to occur between the subsamples, and appropriate weights would need to be recalculated. For example, no sample weights are provided for an overlap between the fasting subsample and the environmental subsample. Refer to the respective survey protocol or documentation for specific information on each subsample.

Fasting weights

Sampled participants aged 12 and over who were examined in a morning session after fasting 8–23 hours, and who had valid glucose readings, have nonzero morning and fasting weights. All other sampled participants examined in a morning session have zero values for the morning and fasting weight variables.

Environmental subsample weights

Some NHANES environmental analytes such as blood lead or blood mercury are obtained on a full sample of participants; therefore, full sample examination weights can be used for analysis. However, most environmental analytes are measured in one-third subsamples. Because each subsample involves another stage of selection, a separate sample weight is calculated that accounts for that stage of selection and any additional nonresponse. For analysis of this subsample data, appropriate subsample weights must be used and are included in the relevant data file.

Because subsamples of NHANES environmental chemicals are most often mutually exclusive, it is not possible to conduct an analysis in which more than one analyte from different subsamples are examined together. For example, in 2005–2006 polyfluorinated compounds were measured in subsample A, but phthalates were measured in subsample B. Sometimes analytes are obtained in the same subsample, and these can be analyzed together with their subsample weights. Most often, these are available for analysis beginning in 2003. For example, in 2007–2008 urinary mercury and urinary arsenic were both measured in the one-third subsample A. As with all data files, users are encouraged to combine like subsample components across survey cycles. For example, 2005–2006 heavy metals were in subsample A, and 2007–2008 heavy metals were in subsample A.

In rare cases, subsamples may overlap with one another but not completely. For example, the participants who were part of the 2003–2004 one-third subsample for urinary arsenic would also be found in the one-half subsample for volatile organic compounds in blood. In this situation, data from the subsamples cannot be combined, and the sample weights cannot be used. If a user

Table E. Formulas for constructing weights: National Health and Nutrition Examination Survey, 1999–2010

Number of survey years	Combined survey cycles	Code[1] with formula for combining weights across survey cycles
4	1999–2002	. . .[2]
	2001–2004	If sddsrvyr in (2,3), then MEC4YR = 1/2 * WTMEC2YR;
	2003–2006	If sddsrvyr in (3,4), then MEC4YR = 1/2 * WTMEC2YR;
	2005–2008	If sddsrvyr in (4,5), then MEC4YR = 1/2 * WTMEC2YR;
	2007–2010	If sddsrvyr in (5,6), then MEC4YR = 1/2 * WTMEC2YR;
6	1999–2004	If sddsrvyr in (1,2), then MEC6YR = 2/3 * WTMEC4YR; /* for 1999–2002 */
		If sddsrvyr = 3, then MEC6YR = 1/3 * WTMEC2YR; /* for 2003–2004 */
	2001–2006	If sddsrvyr in (2,3,4), then MEC6YR = 1/3 * WTMEC2YR;
	2003–2008	If sddsrvyr in (3,4,5), then MEC6YR = 1/3 * WTMEC2YR;
	2005–2010	If sddsrvyr in (4,5,6), then MEC6YR = 1/3 * WTMEC2YR;
8	1999–2006	If sddsrvyr in (1,2), then MEC8YR = 1/2 * WTMEC4YR; /* for 1999–2002 */
		If sddsrvyr in (3,4), then MEC8YR = 1/4 * WTMEC2YR; /* for 2003–2006 */
	2001–2008	If sddsrvyr in (2,3,4,5), then MEC8YR = 1/4 * WTMEC2YR;
	2003–2010	If sddsrvyr in (3,4,5,6), then MEC8YR = 1/4 * WTMEC2YR;
10	1999–2008	If sddsrvyr in (1,2), then MEC10YR = 2/5 * WTMEC4YR; /* for 1999–2002 */
		If sddsrvyr in (3,4,5), then MEC10YR = 1/5 * WTMEC2YR; /* for 2003–2008 */
	2001–2010	If sddsrvyr in (2,3,4,5,6), then MEC10YR = 1/5 * WTMEC2YR;
12	1999–2010	If sddsrvyr in (1,2), then MEC12YR = 1/3 * WTMEC4YR; /* for 1999–2002 */
		If sddsrvyr in (3,4,5,6), then MEC12YR = 1/6 * WTMEC2YR; /* for 2003–2010 */

. . . Category not applicable.

[1]SDDSRVYR is the survey cycle variable: 1 = 1999–2000, 2 = 2001–2002, 3 = 2003–2004, 4 = 2005–2006, 5 = 2007–2008, and 6 = 2009–2010.

[2]The 4-year sample weights for 1999–2002 are included with the public-use data files. Refer to the ''Sample weights for 1999–2000 and 2001–2002'' section.

attempts to combine partially overlapping subsamples, the existing one-third and one-half sample weights would not be appropriate for analysis. It is strongly advised not to attempt to combine different subsamples from a single survey cycle in any analysis.

There are instances in which an analyte may be part of a one-third subsample in one survey cycle and then part of the full sample in another (e.g., urinary iodine was part of the one-third sample in 2005–2006 and part of the full sample in 2007–2008). When analyzing these data, the weights can be adjusted as explained below to analyze the multiyear sample.

Data users interested in the analysis of environmental chemicals are strongly advised to read CDC's ''National Report on Human Exposure to Environmental Chemicals'' (http://www.cdc.gov/exposurereport/). This report contains additional information on the background, data content, public health uses, and interpretation of NHANES data on environmental chemicals.

Table D lists each sample weight (including those calculated for examination and laboratory subsamples) and the appropriate use of each weight. Select the weight variable that applies to all members of the smallest analysis subpopulation. Further details on subsample weights is provided below.

Sample weights for 1999–2000 and 2001–2002

The NHANES 1999–2000 sample weights were based on information from the 1990 U.S. census. The NHANES 2001–2002 sample weights, and all subsequent 2-year cycles, were based on the 2000 census. Because different population bases were used, the 2-year weights for 1999–2000 and 2001–2002 are not directly comparable. For analyses of the combined 1999–2000 and 2001–2002 survey years, 4-year sample weights (i.e., interview, examination, and all subsample weights) were created to account for the two different reference populations. Because NHANES 2003–2004 and all subsequent survey cycles used the same 2000 census counts that were used for NHANES 2001–2002, no other special 4-year weights were needed.

Each 2-year data release file from 1999–2010 includes 2-year interview, examination, and subsample weights. The 1999–2000 and 2001–2002 data release files also contain the 4-year weights. The 4-year sample weights must be used for combined analyses of NHANES 1999–2000 and NHANES 2001–2002 data and when combining any multiple years of data from 1999–2010 that include the 1999–2000 data.

Combining 2-year weights to analyze other multiyear samples

Any 2-year survey cycle may be combined with adjacent 2-year releases to analyze data from multiple survey cycles. NCHS supplies analysts with information on how to combine these cycles and construct the appropriate weights. When combining two or more 2-year cycles from 2001–2002 onward, sample weights must be computed before beginning any analyses. For all data that include 1999–2002, the 4-year weights provided by NCHS must be used and the additional weights for each 2-year cycle must be added. The rules for combining surveys also apply to subsamples. Table E provides the formula for combining weights across survey cycles.

When survey cycles are combined and the weights are constructed appropriately, the estimates will be representative of the U.S. civilian noninstitutionalized population at the midpoint of the combined survey period, and the sum of combined weights should be reasonably close to an independent estimate of that midpoint population. Users should be aware of two assumptions made when combining years of data: (a) that there are no differences in the estimates over the time periods being combined; and (b) in regard to the interpretation, that the estimate is the average over the time period. For details, refer to the Continuous NHANES Tutorial (2), Module 11, ‘‘Weighting.’’

Variance Estimation

The complex multistage probability cluster design of NHANES will affect variance estimates (sampling error). Typically, individuals within a cluster (e.g., county, school, city, or census block) are more similar to one another than to those in other clusters, and this homogeneity of individuals within a given cluster is measured by the intracluster correlation. When working with a complex sample, the ideal situation is to limit the correlation between sample persons within clusters. This is accomplished by sampling fewer people within each cluster but sampling more clusters. However, because of operational limitations (e.g., the cost of moving the survey MECs and the geographic distances between PSUs) NHANES can sample only 30 PSUs within a 2-year survey cycle.

Variance of estimates should be calculated for all survey estimates, using the appropriate methods for complex sample surveys, to aid in determining statistical reliability. However, it is also important to assess the reliability of the estimated variances themselves (see the ‘‘Reliability of the estimated standard error and degrees of freedom’’ section).

Variance estimation methods

For complex sample surveys, exact mathematical formulas for variance estimation are usually not available. Variance approximation procedures are required in order to provide reasonable, approximately unbiased, and design-consistent estimates of variance. Variance estimates computed using standard statistical software packages that assume simple random sampling are generally too low (i.e., significance levels are overstated) and biased because they do not account for the differential weighting and the correlation among sample persons within a cluster.

Two variance approximation procedures that account for the complex sample design are replication methods and Taylor Series Linearization. NCHS recommends that Taylor Series Linearization methods be used for variance estimation in all NHANES 1999–2010 surveys.

For either linearization or replication, strata and PSU variables must be available on the survey data file. Because of confidentiality issues associated with a 2-year data release, true PSUs cannot be provided. To use the Taylor Series Linearization approach for variance estimation, masked variance units (MVUs) were created and provided on the demographic data files. MVUs are equivalent to the pseudo-PSUs that were used to estimate variance in past NHANES. These MVUs on the data file are not the ‘‘true’’ design PSUs, but instead are a collection of secondary sampling units aggregated into groups for variance estimation. They produce variance estimates that closely approximate the variances that would have been estimated using the true design. MVUs have been created for all 2-year survey cycles from NHANES 1999–2000 through 2009–2010. They can also be used for analyzing any combined 4-, 6-, or 8-year data set.

Initially, for the NHANES 1999–2000 survey, the delete-one jackknife method (a replication method) was used to estimate variances. The jackknife method replicate weights are still available on the 1999–2000 data release files. If replication methods are to be used for any other survey years, replicate weights must be computed by the analyst.

Software such as SUDAAN, Stata, SPSS, and SAS survey procedures can all be used to estimate sampling errors by the Taylor Series Linearization method. Software packages that assume a simple random sample should not be used for computing variances for NHANES. The stratum (SDMVSTRA) and PSU (SDMVPSU) needed for Taylor Series Linearization are included in the demographic data file for each data release.

See the NHANES Tutorials (2) for more detail on software programming code for analysis. Refer to the NHANES Estimation report for 2007–2010 (9) and the Sample Design report for 1999–2006 (3) for details on variance estimation.

Other sources of variability

As with any survey, quality control procedures are in place to ensure that sources of error are limited and that the data are of high quality. It is inherent to any measurement process that some sources of variation cannot be controlled, and users should be aware of these. Some variables may be subject to within-person variation. For example, outcomes from a 24-hour dietary intake interview will not be the same if taken on a different day. Also, a person's blood pressure reading could be temporarily elevated due to personal stress and may not equal the average or usual blood pressure reading for that individual. By reading the data collection protocols, users should be in a better position to interpret NHANES data relative to the collection procedures used.

Subsetting Data

An analyst may have a certain demographic subgroup of interest, such as a particular age range or gender, or a subsample of participants who received a particular laboratory test. For proper variance estimation, the entire set of data containing the appropriate weights must be used. The estimation procedure must then indicate which records are in the subgroup of interest. For example, to estimate mean body mass index and its standard error for men aged 20 and over, the entire data set of examined individuals who have an examination weight, including females and individuals younger than 20, must be read into the statistical software program. The SUBPOPN (or SUBPOPX) command in SUDAAN, or the STAT and DOMAIN statements in the SAS survey procedure, must be used to indicate the subgroup of interest (i.e., males aged 20 and over). Prior to running the procedure, an indicator variable should be created to identify only those observations that will be used in the analysis. These observations should all have the appropriate sample weight. Refer to the NHANES Tutorials (2), Module 11 for instructions on creating appropriate subsets of data for NHANES analysis; also see Korn (10) for further details.

Statistical Reliability of Estimates

The issues of precision and statistical reliability should be addressed for each specific analysis. The statistical reliability of an estimate depends on the sample size on which it is based, the design effect and relative standard error (RSE) of the estimate, the reliability of the estimated standard error, and whether the estimate of interest is a rare event or an extreme proportion. Each of these factors is described further in the subsections that follow.

A more reliable estimate may be obtained by increasing the sample size by either collapsing subdomains or combining data from multiple 2-year cycles. An estimate that is considered unreliable in a statistical sense should be noted in any published report, with detail on how statistical reliability was examined. An estimate that is identified as statistically unreliable should not necessarily be suppressed, because it still may be considered significant.

Sample size

Two main requirements were established for NHANES III when considering the utility of a sample for analysis:

- An estimated prevalence statistic should have an RSE of 30% or less.
- Estimated (absolute) differences between domains of at least 10% should be detectable with a Type I error rate (α) of 0.05 or less and a Type II error rate (β) of 0.10 or less.

These two conditions were considered in the sample design of NHANES 1999–2006 and 2007–2010 as well.

To satisfy the first condition, a sample size of about 150 examined persons was necessary. This assumed a design effect of 1.5 resulting from the variability in sampling rates across density strata necessary to accommodate oversampling. The sample necessary to satisfy the second condition was about 420 examined persons. Therefore, the second condition was the more stringent one.

These were the general sample size considerations used in the sample design for NHANES 1999–2010. The population subgroups for which specified reliability was desired are described in the NHANES Sample Design reports for 1999–2006 (3) and 2007–2010 (4). To increase the precision of estimates for certain subgroups, oversampling was carried out for these groups (refer to the previous ‘‘Design changes related to race and Hispanic origin’’ section).

Even though data are released in 2-year cycles, the accumulation of at least 4 years of data may be required in order to obtain an acceptable level of reliability. Thus, to create estimates for smaller 2-year samples, collapsing of some of the subgroups within the sample design may be necessary to produce adequate sample sizes (both in number of observations and number of PSUs) for analysis.

Design effect

The design effect is a measure of the impact of the complex sample design on estimates of variance. It is defined as the ratio of the variance of a statistic that accounts for the complex sample design to the variance of the same statistic based on a hypothetical simple random sample of the same size, as follows:

Design effect = Variance estimate (from clustered sample) / Variance estimate (from simple random sample)

If the design effect is 1, the variance for the estimate under the cluster sampling is the same as the variance under simple random sampling. For NHANES, the design effects are typically greater than 1.

For NHANES 1999–2010, design effects can vary for different variables due to geographical factors, by household intraclass correlation, and by demographic heterogeneity. Because design effects are highly variable for different variables within each 2-year cycle of NHANES, it is difficult to set a single minimum sample size for analysis. The sample size required in order to compute a reliable estimate, and for testing differences between subgroups, depends on the design effect for the variable of interest. The recommended sample sizes for analyses of complex survey data by design effect and specified proportion are provided in Table F. Refer to the NHANES Tutorials (2) and the NHANES III Analytic Guidelines (1) for more detail on design effects.

Relative standard error

The RSE of an estimated statistic is defined as the ratio of the standard error of the estimated statistic to the estimated statistic and is usually expressed as a percentage, as follows:

RSE = (Standard error of estimate / Estimate) * 100

An estimate with a very large RSE may be combined with other estimates to create an aggregate with a reasonably small RSE. When reporting an estimated mean or proportion, it should be marked with an asterisk denoting it as potentially unreliable (in a statistical sense) if its RSE is greater than 30%. The goal is to inform the reader that the computed estimate may potentially be unreliable and caution should be used with any interpretations. Other sources

Table F. Recommended sample sizes for analyses of complex survey data, by design effect and specified proportion

Proportion	Design effect													
	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.5	3.0	3.5
0.99	800	880	960	1,040	1,120	1,200	1,280	1,360	1,440	1,520	1,600	2,000	2,400	2,800
0.95	160	176	192	208	224	240	256	272	288	304	320	400	480	560
0.90	80	88	96	104	112	120	128	136	144	152	160	200	240	280
0.85	53	59	64	69	75	80	85	91	96	101	107	133	160	187
0.80	40	44	48	52	56	60	64	68	72	76	80	100	120	140
0.75	32	35	38	42	45	48	51	54	58	61	64	80	96	112
0.56–0.74	30	33	36	39	42	45	48	51	54	57	60	75	90	105
0.55	30	33	36	39	42	45	48	51	54	57	60	75	90	105
0.50	30	33	36	39	42	45	48	51	54	57	60	75	90	105
0.45	30	33	36	39	42	45	48	51	54	57	60	75	90	105
0.26–0.44	30	33	36	39	42	45	48	51	54	57	60	75	90	105
0.25	32	35	38	42	45	48	51	54	58	61	64	80	96	112
0.20	40	44	48	52	56	60	64	68	72	76	80	100	120	140
0.15	53	59	64	69	75	80	85	91	96	101	107	133	160	187
0.10	80	88	96	104	112	120	128	136	144	152	160	200	240	280
0.05	160	176	192	208	224	240	256	272	288	304	320	400	480	560
0.01	800	880	960	1,040	1,120	1,200	1,280	1,360	1,440	1,520	1,600	2,000	2,400	2,800

NOTE: Minimum sample size requirements were adjusted for the relative inefficiency in the sample design by a factor equal to the design effect, where design effect = complex sample variance/simple random sample variance. For midrange proportions (p greater than 0.25 and less than 0.75), the simple random sample (SRS) minimum sample size is 30. For extreme proportions ($p \leq 0.25$ or $p \geq 0.75$), the SRS sample size (n) satisfies the following rule: $n(p) \geq 8$ and $n(1 - p) \geq 8$.

SOURCE: CDC/NCHS, adapted from NHANES III Analytic Guidelines; see reference 10.

may use different criteria to assess the statistical reliability of NHANES data (e.g., RSE greater than 20% or greater than 25%).

Reliability of the estimated standard error and degrees of freedom

As discussed previously, the standard error of a statistic estimated from NHANES data is also an estimate, and as such is subject to its own variability. The reliability of the estimated standard error, as measured by its RSE, is inversely proportional to the square root of its degrees of freedom. The nominal degrees of freedom is calculated by subtracting the number of PSU sampling strata from the number of PSUs, as follows:

Nominal degrees of freedom =
Number of PSUs – Number of strata

If an analysis is performed on a subgroup of cases, the number of strata and the number of PSUs are counted based on the number of strata and PSUs that contain the observations of interest. For example, if the standard error of the mean systolic blood pressure for non-Hispanic black persons is based on 25 PSUs and 13 strata, then the degrees of freedom would be 25 – 13 = 12.

As the number of degrees of freedom increases, the RSE of the estimated standard error decreases and, therefore, the reliability of the estimated standard error increases. So, standard error estimates based on small numbers of degrees of freedom are prone to instability. If an estimated standard error has at least 12 degrees of freedom, the RSE of the standard error will be 30% or less. For more detail on computing degrees of freedom, refer to the NHANES Tutorials (2).

Rare events and extreme proportions

The Central Limit Theorem guarantees that statistics based on a sufficiently large sample are approximately normally distributed. For proportions between 0.25 and 0.75 based on NHANES, an effective sample size (i.e., an actual sample size divided by a broadly calculated or average design effect) of at least 30 is needed. For extreme proportions (i.e., less than 0.25 based on rare events or greater than 0.75 based on frequent events), a much larger sample is required. For this reason, combining two or more adjacent NHANES 2-year cycles is highly recommended. Table F gives the recommended sample sizes for analyses of complex survey data by design effect and specified proportion.

Confidence intervals (CIs) should also be examined when assessing the reliability of extreme proportions. An extreme proportion may have an RSE exceeding 30% but have a fairly short CI. A CI gives a range of plausible values of a population parameter, such as a population mean, geometric mean, or percentage. They yield a measure of the variability of the point estimate of the parameter obtained by taking a probability sample of the population.

Both SAS survey procedures (proc surveymeans) and SUDAAN version 11.0 (proc descript or crosstab) produce 95% CIs. These 95% CIs are constructed using the Wald method, which is based on a t statistic for the number of degrees of freedom in the entire NHANES sample. However, these procedures do not correct for the reduction in the degrees of freedom in subdomains where not all strata and PSUs are represented. For a small proportion (less than 0.25), the Wald method may result in a negative lower limit, whereas for a high proportion (greater than 0.75) it may result in an upper limit that exceeds 1. In these cases, it is often recommended to use alternative methods for calculating 95%

CIs using transformations (such as, the logit or arcsine transformation), using the Wilson method, or constructing exact CIs such as the Clopper-Pearson approach. Refer to the NHANES Tutorials (2) for further details.

Age Adjustment

Age adjustment—sometimes referred to as age standardization—is a method that applies observed age-specific rates to a standard age distribution. It is used when comparing two or more populations at one point in time, or one population at two or more points in time. This method removes the confounding effect of age, which can distort comparisons between groups with different age distributions when age is related to the outcome of interest (e.g., death or the prevalence of disease). Although many factors affect health outcomes, age is generally the strongest because the chance of developing or dying from chronic health conditions typically increases with age; also, different age groups might have differential exposure to behavioral or environmental risks. An age-standardized prevalence comparison is a comparison between groups, assuming both groups have exactly the same age structure. Crude estimates can also be important. The reporting of crude or age-adjusted estimates should be made based on the primary focus of the analysis. If a statistic of interest varies substantially by age (i.e., within racial and ethnic categories), the age-standardized estimates may be more appropriate when comparing across groups with different age distributions.

Age adjustment is important to consider for trend analyses between the various NHANES and for comparisons between subgroups with different age distributions within NHANES (for example, non-Hispanic white, non-Hispanic black, and Mexican-American persons). Two methods of age adjustment are widely used: direct and indirect (11). In both cases, the general idea is to construct an estimate based on what would be seen if the age distributions in the comparison groups were the same. The two basic steps are described as follows:

- *Choose a standard population*. In general, the standard population can be a single study group, a combined study group, or an external population (i.e., the U.S. population). For NHANES 1999–2010, the standard population typically used is the year 2000 population projections from the U.S. Census Bureau (11).
- *Apply the age-specific prevalence in the* study *population (i.e., the population to age-adjust) to the* standard *population*. This is typically done in 5- or 10-year age groups. The age-adjusted prevalence is obtained by multiplying the age-specific prevalence in the study population by the proportion of people in that age group in the standard population, and summing the results.

The following standard proportions are based on the 2000 standard population and should be used in NHANES 1999–2010 analyses when using 20-year age groups for ages 20 and over:

Age group	*Proportion*
20–39	0.3966
40–59	0.3718
60 and over	0.2316

As mentioned earlier, prior to NHANES III, NHES and NHANES had upper age limits, so trends need to be conducted on ages 20–74. Consequently, to compare age-adjusted estimates for NHANES 1999–2010 with these surveys, the following standard proportions should be used:

Age group	*Proportion*
20–39	0.4332
40–59	0.4062
60–74	0.1606

Any comparison of age-adjusted rates requires that the same standard population and the same age groups be used. For example, it is not appropriate to compare an age-adjusted rate from NHANES III based on the 1990 standard with an age-adjusted rate from NHANES 1999–2000 based on the 2000 standard. For more detail on age adjustment, refer to the NHANES Tutorials (2) and Klein and Schoenborn (11).

Computing Population Counts

To understand the public health impact of a condition, it is often helpful to calculate population counts in addition to the prevalence of a health condition. By quantifying the number of people with a particular condition or risk factor, counts speak directly to the burden or magnitude. There are a few basic steps to calculating a population count [refer to the NHANES Tutorials (2) for further details]:

1. Calculate the unadjusted (crude) prevalence of the health condition or risk factor.
2. Use the relevant population totals from the CPS to determine population estimates in NHANES. Because NHANES is a nationally representative survey of the civilian noninstitutionalized U.S. population, population estimates are based on the CPS totals for this aspect of the U.S. population. Use CPS totals for the midpoint of each survey cycle. CPS-based population tables for NHANES by race and ethnicity, gender, and age are available from: http://www.cdc.gov/nchs/nhanes/response_rates_CPS.htm. When combining NHANES cycles, use the midpoint of each cycle to obtain the CPS totals. For example, when combining NHANES 2001–2002 and 2003–2004, combine them as follows to obtain a population total for 2001–2004:

   ½ (NHANES 2001–2002 population totals) + ½ (NHANES 2003–2004 population totals)

   The only exception would be when combining NHANES 1999–2000 with 2001–2002, because these survey years used a different reference population for sampling. Population totals for 1999–2002 are provided by NCHS at http://www.cdc.gov/nchs/nhanes/response_rates_CPS.htm.
3. Multiply the prevalence of the risk factor or health condition of interest by the corresponding CPS-based population total to obtain an estimate of the number of

noninstitutionalized U.S. individuals with the risk factor or condition. To calculate age-, sex-, or race and ethnicity-specific population estimates, multiply the prevalence of the health condition in each subdomain by the CPS population total for the respective subdomain.

4. Population totals should be reported to the nearest thousand, with a 95% CI based on the 95% CIs computed from the prevalence estimate.

Although the noninstitutionalized CPS population totals are used to calculate the final sampling weights for NHANES, the sum of the final sampling weights for all sample persons with the risk factor or health condition of interest cannot be used to arrive at population estimates. The total population estimate for a given risk factor or health condition from the interviewed sample should equal the sum of the final interview weights for individuals with that health condition. However, if there are a significant number of exclusions or missing data for a health condition, summing the weights will not produce an accurate population estimate. Therefore, use of this method is not recommended.

Note that the population totals generated in NHANES can only be representative of the number of individuals with the health condition in the civilian noninstitutionalized U.S. population.

Conclusion

These analytic guidelines represent the latest statistical procedures and analytic guidance for the continuous NHANES for 1999–2010. If significant changes occur in the NHANES design, or if new statistical techniques for the analysis of complex sample surveys are introduced, these guidelines will be updated to reflect the changes.

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Appendix. Glossary

Domain—A demographic group of analytic interest (analytic domain). Analytic domains may also be sampling domains if a sample design is created to meet goals for those specific demographic groups. For the National Health and Nutrition Examination Survey (NHANES), sampling domains are defined by race and Hispanic origin, income, age, and sex.

Dwelling unit (DU), also *housing unit*—A house, apartment, mobile home or trailer, group of rooms, or single room occupied as separate living quarters (see *Group quarters*) or, if vacant, intended for occupancy as separate living quarters. Separate living quarters are those in which the occupants live separately from other individuals in the building and which have direct access from outside the building or through a common hall. In this report, the term generally means those DUs that are eligible for the survey (i.e., excluding institutional group quarters), or that could become eligible (e.g., vacant at the time of sampling, but which might be occupied once screening begins).

Group quarters—A place where people live or stay that is normally owned or managed by an entity or organization providing housing or services for the residents. These services may include custodial or medical care, as well as other types of assistance, and residency is commonly restricted to those receiving these services. People living in group quarters usually are not related to each other. Group quarters include such places as college residence halls, residential treatment centers, skilled nursing facilities, group homes, military barracks, correctional facilities, workers' dormitories, and facilities for people experiencing homelessness. These are generally grouped into two categories: institutional group quarters and noninstitutional group quarters.

Institutional group quarters—Group quarters providing formally authorized, supervised care or custody in an institutional setting, such as correctional facilities, nursing and skilled nursing facilities, inpatient hospice facilities, mental health or psychiatric facilities, and group homes and residential treatment centers for juveniles. Institutional group quarters are not included in the NHANES sample.

Noninstitutional group quarters—Group quarters that do not provide formally authorized, supervised care or custody in an institutional setting. These include college and university housing, group homes intended for adults, residential treatment facilities for adults, workers' group living quarters, Job Corps centers, and religious group quarters. Noninstitutional group quarters are included in the NHANES sample.

Household—The person or group of persons living in an occupied DU.

Masked variance units (MVUs)—A collection of secondary sampling units aggregated into groups for variance estimation and designed to prevent disclosure of the identity of the selected primary sampling units (PSUs). For NHANES, rather than using the units as sampled, some pseudounits are created by swapping segments between PSUs. The resulting units produce variance estimates that closely approximate the "true" design variance estimates. MVUs have been created for all 2-year survey cycles from NHANES 1999–2000 through 2009–2010. They can also be used for analyzing any combined 4-, 6-, or 8-year data set.

National Center for Health Statistics (NCHS)—As the nation's principal health statistics agency, NCHS designs, develops, and maintains a number of systems that produce data related to demographic and health concerns. These include data on registered births and deaths collected through the National Vital Statistics System, and data collected by the National Health Interview Survey, NHANES, the National Health Care Surveys, and the National Survey of Family Growth, among others. NCHS is part of the Centers for Disease Control and Prevention, an operating division of the U.S. Department of Health and Human Services.

Noninstitutionalized civilian population—Includes all people living in households, excluding those in institutional group quarters and those on active duty with the military. This is the target population for NHANES.

Primary sampling unit (PSU)—The first-stage selection unit in a multistage area probability sample. In NHANES, PSUs are counties or groups of counties in the United States. Some PSUs are so large that they are selected into the survey with a probability of one. These are referred to as PSUs selected with certainty ("certainty PSUs"); all other PSUs are selected without certainty ("noncertainty PSUs").

Public-use data file—An electronic data set containing respondent records from a survey with a subset of variables collected in the survey that have been reviewed by analysts within NCHS to ensure that respondent identities are protected. NCHS disseminates these files to encourage public use of the survey data.

Race and Hispanic origin—This phrase is used in this report as it was used in NHANES sample selection. It refers to Hispanic persons, non-Hispanic black persons, and a third group consisting of all other persons.

Respondent—A person selected into a sample who agrees to participate in all aspects of a survey. In NHANES, persons agreeing to complete the in-home interview are "interview respondents." Persons agreeing to complete both the in-home interview and an examination in a mobile examination center (MEC) are "MEC respondents."

Response rate—The number of survey respondents divided by the number of persons selected into the sample. The response rates in this report are MEC response rates—calculated as the number of people receiving examinations in the MEC divided by the total number of people sampled.

Restricted-use data file—An electronic data set of survey respondent records containing some information that may, if released to the public, risk disclosing individual survey respondents. These data are available only through the NCHS Research Data Center (RDC). Included are data sets with (a) data items collected for an odd number of calendar years (1, 3, or 5 years); (b) data geographically linked to other contextual data files (often supplied by the data user); (c) data items determined to be too sensitive or too detailed to be released to the public due to confidentiality restrictions; and (d) surplus sera projects where past biological samples have been stored and subsequently used based on a formal proposal submitted as a special study (on either the full sample or a special subsample).

Sample weight—The estimated number of persons in the target population that an NHANES respondent represents. For example, if a man in the sample represents 12,000 men in his race-Hispanic origin-income-age subdomain, then his sample weight is 12,000. The NHANES sample weights were adjusted for different sampling rates (of the race-Hispanic origin-income-sex-age groups), different response rates, and different coverage rates among persons in the sample, so that accurate national estimates could be made from the sample. The product of all of these adjustments is sometimes called the ''final'' sample weight.

Sampling rate—The rate at which a unit is selected from a sampling frame. For NHANES, the rates required for sampling persons in the race-Hispanic origin-income-sex-age domains were designed to achieve the designated number of MEC examinations in each of those domains. The sampling rates are the driving force in all stages of sampling.

Screener—An interview (usually short) containing a set of questions asked of a household member to determine whether the household contains anyone eligible for the survey. In NHANES, the screener consisted of compiling a household roster and collecting the income level of the household and the race and Hispanic origin, age, and sex of all household members. In NHANES, only persons aged 18 and over can answer the screener.

Screening—The process of conducting, or attempting to conduct, the screener interview in selected DUs. Occupied DUs (households) are screened using the screener. Other units can also be screened; to verify that they are either vacant or not DUs. See *Screener*.

Secondary sampling unit—The second-stage selection unit in a multistage area probability sample. For NHANES, these are typically referred to as ''segments.'' See *Segment*.

Segment—A group of housing units located near each other, all of which were considered for selection into the sample. For NHANES, segments consist of a census block, or groups of blocks, and their selection makes up the second stage of sampling. Within each segment, a sample of DUs was selected.

Stratification, strata—The partitioning of a population of sampling units into mutually exclusive categories (strata). Typically, stratification is used to increase the precision of survey estimates for subpopulations important to the survey's objectives. To select the PSUs fielded in 2007–2010, PSUs were stratified based on region, metropolitan statistical area status, and various population demographics.

Variance—A measure of the dispersion of a set of numbers. In this report, the variance is specifically the sample variance, which is a measure of the variation of a statistic such as a proportion or a mean, calculated as a function of the sampling design and the population parameter being estimated. Many common statistical software packages compute ''population variances'' by default; these may underestimate the sampling variance because they do not incorporate any effects of having taken a sample instead of collecting data from every person in the full population. Estimating the variance in NHANES requires special statistical software, as discussed in this report.

Variance unit—A collection of secondary sampling units aggregated into groups and excluded when forming a replicate for variance estimation. For NHANES, an entire PSU usually corresponds to a variance unit.

Weight—See *Sample weight*.

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