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National Health and Nutrition Examination Survey: Sample Design, 2007–2010

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
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Data Evaluation and Methods Research

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Hyattsville, Maryland
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Abstract

Background

Data collection for the National Health and Nutrition Examination Survey (NHANES) comprises three levels: a household screener, an interview, and a physical examination. The primary objective of the screener is to determine whether any household members are eligible for the interview and examination. Eligibility is determined by preset selection probabilities for the desired demographic subdomains. After an eligible sample person is selected, the interview collects person-level demographic, health, and nutrition information, as well as information about the household. The examination includes physical measurements, tests such as hearing and dental examinations, and the collection of blood and urine specimens for laboratory testing.

Objectives

This report provides some background on the NHANES program, beginning with the first survey cycle in the 1970s and highlighting significant changes since its inception. The report then describes the broad design specifications for the 2007–2010 survey cycle, including survey objectives, domain and precision specifications, and operational requirements unique to NHANES. In addition, the report describes the details of the survey design, including the calculation of sampling rates and sample selection methods. Documentation of survey content, data collection procedures, estimation methods, and methods to assess nonsampling errors are reported elsewhere.

Keywords: weighting • sampling rates • NHANES

National Health and Nutrition Examination Survey: Sample Design, 2007–2010

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Introduction

The National Health and Nutrition Examination Survey (NHANES) is one of a series of health-related programs conducted by the Centers for Disease Control and Prevention's National Center for Health Statistics (NCHS). A unique feature of this survey is the collection of health examination data for a nationally representative sample of the resident civilian noninstitutionalized U.S. population. The survey consists of questionnaires administered in the home, followed by a standardized health examination in specially equipped mobile examination centers (MECs).

NHANES provides information on the noninstitutionalized civilian resident population of the United States. It 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 of the 50 states and the District of Columbia. Noninstitutional group quarters are included in the sample; see the Glossary (Appendix I) for more details on institutional and noninstitutional group quarters.

NHANES I, the first cycle of NHANES, was conducted during 1971–1975; two other cycles, and a cycle focusing on the Hispanic population (HHANES), were conducted between 1976 and 1994. NHANES was fielded again in 1999 and, in the tradition of the past national surveys, it continues to provide information on the health and nutritional status of the U.S. population. This information is used to estimate the prevalence of various diseases and conditions and to provide information for many public health functions (e.g., reference data, nutrition and health monitoring, and prevention initiatives).

The sample design used since 1999 allows the production of aggregate-level national estimates from NHANES each year. Annual samples are nationally representative; however, annual estimates should be produced only for the nation as a whole, for race and Hispanic origin subdomains, or for very broad sex-age subdomains within race and Hispanic origins, because of limited sample sizes and larger variances of point estimates (data on the annual sample are not publicly available).

Differences in the sample sizes and designs for all cycles of NHANES and for HHANES should be considered when comparisons are made across the various surveys. For example, NHANES I, NHANES II, and HHANES did not include persons aged 75 and over, and NHANES I and NHANES II did not oversample Hispanic persons or black persons. The NHANES 1999–2006 sample included a supplemental sample of pregnant women. NHANES 1999–2006 also included an oversample of Mexican-American persons. The

domains being oversampled in NHANES 2007–2010 changed from NHANES 1999–2006—the primary change was the oversampling of the entire Hispanic population instead of only the Mexican-American population. The oversample of adolescents and the supplemental sample of pregnant women in the 1999–2006 survey were discontinued. The sample design parameters for the six HANES surveys are compared in Table A.

Data collection for NHANES comprises three levels: a household screener, an interview, and an examination, including selected objective measures of health status. The primary objective of the screener is to determine whether any household members are eligible for the interview and examination. The interview collects person-level demographic, health, and nutrition information, as well as information about the household. The examination includes physical measurements, such as blood pressure, dental examination, and the collection of blood and urine specimens for laboratory testing.

Because NHANES can only cover a small number of primary sampling units (PSUs) each year, parameter estimates for single-year data are relatively unstable (large variance estimates). In addition, releasing only 1 year of data increases the possibility of disclosure of

Table A. Selected sample design parameters: Health and Nutrition Examination Surveys, 1971–2010

Characteristic	NHANES I 1971–1974	NHANES II 1976–1980	Hispanic HANES 1982–1984	NHANES III 1988–1994	NHANES 1999–2006	NHANES 2007–2010
Age of noninstitutionalized civilian target population	1–74 years	6 months–74 years	6 months–74 years	2 months and over	All ages from birth	All ages from birth
Geographic areas	United States (excluding Alaska and Hawaii)	United States	Southwest for Mexican-American population NY, NJ, CT for Puerto Rican population Dade County, FL, for Cuban population	United States	United States	United States
Average number of sample persons per eligible household	1	1	2.71[1,2]	2.03[1,2]	2.02[1]	2
Number of study locations	100	64	17 in Southwest; 9 in NY, NJ, CT; 4 in Dade County, FL	89	117	60
Domains for oversampling	Low income (at or below 100% of federal poverty level): Children aged 1–5 years; Women aged 20–44; Persons aged 65–74	Low income (at or below 100% of federal poverty level): Children aged 6 months–5 years; Persons aged 60–74 years	Southwest; NY, NJ, and CT; and Dade County, FL: Persons aged 6 months–19 years and 45–74 years	Predesignated: 52 subdomains of sex-age groups for black, Mexican-American, and other persons Oversampled: Mexican-American persons, black persons, young children (under age 1 year), and adults aged 60 and over	Predesignated: 76 subdomains[1] of sex-age groups for black persons and Mexican-American persons, and income-sex-age groups for other persons Oversampled: Mexican-American persons, black persons, low-income white and other persons (at or below 130% of federal poverty level), adolescents aged 12–19, and non-Hispanic white and other adults aged 70 and over. A supplemental sample included pregnant women	Predesignated: 72 subdomains[2] of sex-age groups for non-Hispanic black persons and Hispanic persons, and income-sex-age groups for other persons Oversampled: Hispanic persons, non-Hispanic black persons, low-income non-Hispanic white and other persons (at or below 130% of federal poverty level), and non-Hispanic white and other adults aged 80 and over
Number of selected persons	28,043	27,801	15,924	39,695	50,939	26,215
Number of interviewed persons	27,753	25,286	13,689	33,994	41,474	20,686
Number of examined persons	20,749	20,322	11,653	30,818	39,352	20,015

[1]In 1999, 53 subdomains were predesignated for black, Mexican-American, and other persons.

[2]Compared with previous age-sex domains, age domains 12–15 and 16–19 were combined, and age-minority domain 40–59 was split into 10-year age domains (40–49 and 50–59).

NOTE: NHANES is National Health and Nutrition Examination Survey; Hispanic HANES is Hispanic Health and Nutrition Examination Survey.

Table B. Sampling subdomains classified by race and Hispanic origin, income, sex, and age: National Health and Nutrition Examination Survey, 2007–2010

Sex	Non-Hispanic black	Hispanic	Non-Hispanic white and other	
			Non-low income	Low income[1]
		Age (years)		
Males and females	Under 1	Under 1	Under 1	Under 1
	1–2	1–2	1–2	1–2
	3–5	3–5	3–5	3–5
Males	6–11	6–11	6–11	6–11
	12–19	12–19	12–19	12–19
	20–39	20–39	20–29	20–29
	. . .	. . .	30–39	30–39
	40–49	40–49	40–49	40–49
	50–59	50–59	50–59	50–59
	60 and over	60 and over	60–69	60–69
	. . .	. . .	70–79	70–79
	. . .	. . .	80 and over	80 and over
Females	6–11	6–11	6–11	6–11
	12–19	12–19	12–19	12–19
	20–39	20–39	20–29	20–29
	. . .	. . .	30–39	30–39
	40–49	40–49	40–49	40–49
	50–59	50–59	50–59	50–59
	60 and over	60 and over	60–69	60–69
	. . .	. . .	70–79	70–79
	. . .	. . .	80 and over	80 and over

. . . Category not applicable.
[1]At or below 130% of federal poverty level.

a sample person's identity. These two factors resulted in the decision to publicly release data in 2-year cycles. Annual estimates may only be made through the NCHS Research Data Center. To improve the statistical reliability and stability of estimates, analysts are advised to use combinations of 2-year cycles. Combining data from 2-year cycles is particularly appropriate for rare events, for estimates pertaining to detailed demographic subdomains, and for measures that may have considerable geographic variation.

This report describes the broad design specifications for the 2007–2010 survey, including survey objectives, domain and precision considerations, and operational requirements. In addition, the report describes the details of the survey design, including the calculation of sampling rates and sample selection methods.

More information about the 2007–2010 estimation procedures, the creation of weights for the entire sample and subsamples, and appropriate variance estimation methods to be used when analyzing NHANES data can be found in ''National Health and Nutrition Examination Survey: Estimation Procedures, 2007–2010.'' Other documentation of the survey content, data collection procedures, and methods to assess nonsampling errors is reported elsewhere; visit http://www.cdc.gov/nchs/nhanes.htm for more information.

Design Specifications

Survey Objectives

A primary objective of NHANES 2007–2010 is to produce a broad range of descriptive health and nutrition statistics for sex, race and Hispanic origin, and age subdomains of the U.S. population. These data can then be used to measure and monitor the health and nutritional status of the civilian noninstitutionalized population. The analytic goals of NHANES are to:

- Estimate the number and percentage of persons in the U.S. population and in designated subgroups with selected diseases and risk factors.
- Monitor trends in the prevalence, awareness, treatment, and control of selected diseases.
- Monitor trends in risk behaviors and environmental exposures.
- Study the relationship among diet, nutrition, and health.
- Explore emerging public health issues and new technologies.
- Collect a national probability sample of genetic material for genetic research.
- Provide baseline health characteristics that can be linked to mortality data from the National Death Index or other administrative records (e.g., enrollment and claims data from the Centers for Medicare & Medicaid Services).

Domain and Precision Considerations

The set of domains for which specified reliability was desired in NHANES 2007–2010 consisted of sex-age groups for non-Hispanic black persons, Hispanic persons, and the remainder of the U.S. population. Table B provides the set of sampling domains in NHANES 2007–2010. To increase the precision of estimates for certain subdomains, oversampling was carried out for Hispanic persons, non-Hispanic black persons, and non-Hispanic white and other persons at or below 130% of the federal poverty level, and for non-Hispanic white and other persons aged 80 and over. Although data are released in 2-year cycles, the accumulation of at least 4 years of data is required to obtain an acceptable level of reliability for the domains given in Table B. Thus, to create estimates for 2 years (or any annual estimates), collapsing of some sampling domains is necessary to produce adequate sample sizes for analysis purposes.

The NHANES 2007–2010 sample was designed to produce data that would meet the following two conditions:

1. An estimated prevalence statistic of approximately 10% in a sex-age domain should have a relative standard error of 30% or less.
2. 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.

To satisfy the first condition, a sample size of about 150 examined persons is needed. This assumes 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 is about 420 examined persons.

These are the general sample-size considerations used in the sample design and provide guidance as to whether the data can meet analytic objectives. For example, for a very small demographic group, combining 4 years of NHANES data for a specific variable and a specific analysis may be necessary. However, the sample design effects for each measured NHANES variable, and for specific demographic subdomains, can be quite different from the assumed general design effect of 1.5. The issues of precision and statistical power should be addressed for each specific analysis.

Operational Requirements

A unique feature of NHANES is the collection of physical examination data for each respondent in the sample. To standardize their administration, these examinations are carried out in MECs. Three separate MECs are in service at any given time. Following a carefully designed schedule, two MECS are in operation at study locations while the third is either traveling or being prepared for operation at a new location.

To maintain a cost-efficient workload within each location while considering the time and the cost involved in moving a MEC between study locations, the maximum number of study locations NHANES may go to in each annual sample is 15. Based on this, the number of sampled participants selected in each study location should be between 300 and 600, with an average of approximately 450, to yield approximately 333 examined persons in each of the 15 locations for that year.

Previous experience with other NHANES surveys indicates that response rates increased when a larger sample of persons was selected within households. One of the factors thought to be responsible for the increased response rates in these households was that each person was given remuneration for his or her time and participation. Therefore, another important factor considered in the final design was to maximize the response rates and reduce screening costs by selecting as large an average number of sampled participants per household as possible. Another factor affecting response rates is the amount of travel necessary for respondents to visit a MEC. The PSUs for NHANES are typically defined as individual counties, rather than combinations of counties as in other area surveys, to increase the likelihood of achieving high response rates.

Sample Design

The NHANES sample represents the total noninstitutionalized civilian U.S. population residing in the 50 states and the District of Columbia. As with previous NHANES samples, a four-stage sample design was used in NHANES 2007–2010. The first stage consisted of selecting the PSUs from a frame of all U.S. counties. The first-stage PSUs were mostly counties; in a few cases, adjacent counties were combined to keep PSUs above a certain minimum size. NHANES PSUs were selected with probabilities proportionate to a measure of size (PPS).

The second stage of selection for the NHANES 2007–2010 sample included a sample of area segments, comprising census blocks or combinations of blocks. However, because these samples were based on 2000 census data, the measure of size (MOS) used for sampling was updated, if necessary, for PSUs experiencing large growth since 2000.

The sample was designed to produce approximately equal sample sizes per PSU, and noncertainty PSUs have 24 segments. PSUs selected with certainty (with a probability of one) may have more or fewer than 24 segments, to ensure appropriate representation in the sample. Additionally, some large certainty PSUs were treated as multiple study locations with varying numbers of segments in each location to, again, ensure appropriate representation of the PSU. The segments were also selected with PPS. The MOS of the segments, when combined with the subsampling rates used within the segments, provided approximately equal numbers of sampled participants per segment.

The third stage of sample selection consisted of dwelling units (DUs), including noninstitutional group quarters such as dormitories. In a given PSU, following the selection of segments, a listing of all DUs in the sampled segments was prepared, and a subsample of these were designated for screening to identify potential sampled participants. The subsampling rates were set up to produce a national, approximately equal probability sample of households. The screening rate was designed to produce the desired number of sampled participants for the most difficult race-Hispanic origin-sex-age-income domain (i.e., the domain sampled at the highest rate).

The fourth stage of sample selection consisted of persons within occupied DUs, or households. All eligible members within a household were listed, and a subsample of individuals was selected based on sex, age, race and Hispanic origin, and income. The subsampling rates and designation of potential sampled participants within screened households were arranged to provide approximately self-weighting samples for each subdomain and to maximize the average number of sampled participants per sample household.

Expected annual sample sizes at the design stage are:

- Study locations 15
- Segments 360
- DUs to be screened 12,637
- Households to be screened 11,500
- Sampled persons 6,525
- Examined persons 5,000

Sampling Rates

The rates required for sampling race-Hispanic origin-sex-age-income domains are the driving force in all stages of sampling for NHANES.

Calculation of screening amounts and sampling rates to achieve self-weighting sample within each domain

NHANES is a multistage, national area probability survey with fixed sample-size targets for sampling domains defined by race and Hispanic origin, sex, age, and low-income status. Thus, the first step in determining the MOS to be used for sampling at each stage is to calculate the sampling rate for each domain. The sampling rate for a domain depends on the target examination sample size, the expected examination response rate, and the estimated population size. These sampling rates determine the amount of screening that will be required.

To calculate sampling rates, it is necessary to set expectations for response rates. Expected examination response rates were set equal to achieved examination response rates by domain for NHANES 2002–2004, with Mexican-American response rates used to predict Hispanic response rates. The response rates used in the calculations ranged from 54% to 94%, with the lowest response rates assigned to the most challenging sampling domains, such as persons aged 60 and over.

Several data sources were used to obtain national estimates of the 2008 noninstitutionalized civilian population by race and Hispanic origin for the NHANES 2007–2010 sample. At the time of PSU selection, population projections were not available for certain U.S. subpopulations, such as noninstitutional civilian residents, so multiple data sources were needed to create these estimates. Sex-age distributions for Hispanic persons, non-Hispanic black persons, and the entire U.S. population were from the U.S. Census Bureau's projections of the total resident U.S. population for 2008. The proportion of the total resident population that is civilian and living outside of institutions, as well as the proportion of the non-Hispanic black population that is black alone (not in combination with other races), in each sex-age domain were calculated from census population estimates for 2003. National poverty estimates for white persons and others (non-black, non-Hispanic) were derived from the Census Bureau's March 2004 Current Population Survey (CPS).

The information in Table I (Appendix II) was used to determine the overall sample size required to meet each domain target in NHANES 2007–2010. Among non-Hispanic black persons, the domain requiring the most screening contained males aged 60 and over; 41,659 households were expected to be screened to meet the 4-year target for this domain. The domain requiring the most screening among non-Hispanic white persons and others contained low-income males aged 80 and over (no explicit target sample sizes exist for infants, aged under 1 year); 33,395 households were expected to be screened to meet the 4-year target for this domain. The domain requiring the most screening among Hispanic persons contained males aged 60 and over, and 56,050 households were expected to be screened to meet the 4-year target for this domain.

A within-domain self-weighting sample would require screening an expected 14,012 households each year to achieve the target number of examinations in every sampling domain. The previous NHANES designs averaged around 11,500 screened households per year. For operational reasons, it was desirable to limit the screening to about the same level for the 2007–2010 design. An annual screening sample of 11,000 would achieve targets for all domains except Hispanic males aged 60 and over. With 11,000 screened households each year, the expected number of examined Hispanic males aged 60 and over would be 472. This is 128 fewer Hispanic males than the targeted number. With 11,500 screened households, the expected number of examined Hispanic males aged 60 and over would be 492.

A within-domain self-weighting sample of approximately 12,637 DUs per year, resulting in 11,500 screened households, was used for NHANES 2007–2010 (this assumes that 9% of the DUs were either vacant or included in the sample in error, such as a structure thought to be a residence that was actually a business). The total expected screening for the 4-year sample is 46,000 households. However, to ensure that the targeted number of sampled persons could be reached in the event of unexpected occurrences during the field period, additional households were selected and held in reserve. The following is a derivation of the screening rate for the full 4-year sample:

- Screening sample size for 4 years: 46,000 households
- Fifty percent add-on for reserve: 69,000 households
- Projected total U.S. households in 2008: 111,628,395 households
- Maximum sampling rate: 69,000/111,628,395 ≈ 1/1,618.

Final sampling rates

Table II (Appendix II) shows the sampling rates used for the selection of PSUs in NHANES 2007–2010 for each of the sampling domains. The sampling rates given in Table I (Appendix II) were designed to provide a 50% reserve sample, as well as a provision for expected nonresponse in each subdomain. Note that midway through 2008, the reserve size was changed to 80%. This increase was made by increasing the DU selection rate and was reflected in the calculation of base weights; the within-DU selection rates were unchanged.

Sampling rates were calculated using the approach described in the previous ''Calculation of screening amounts and sampling rates to achieve a self-weighting sample within each domain'' section. All screened persons in the subdomain having that maximum rate were to be retained in the sample. The screened persons in other subdomains were to be subsampled to bring the sampling rates for those subdomains down to the desired levels. The subsampling rates were designed to minimize the variability in sampling rates among strata while still achieving the desired precision.

Departures from self-weighting sample

Calculating the sampling rates required several assumptions related to population size and response rates. To the extent that these assumptions were not met, the actual screening required to reach the target sample sizes differed from the expected screening. As stated in the previous ''Calculation of screening amounts and sampling rates to achieve a self-weighting sample within each domain'' section, several data sources were used to develop the 2008 population projections used in the sampling rate calculations, including the U.S. Census Bureau's 2008 projections of the resident population by age, sex, and race and Hispanic origin; its 2003 postcensal estimates of the resident and noninstitutionalized civilian population, as well as the ratio of the non-Hispanic black multirace population to the non-Hispanic black-alone population in each sex-age domain; and the March 2004 CPS national poverty estimates for white persons and others. The population projections and resulting expected screening requirement numbers depended on the assumption that these 2003, 2004, and 2008 proportions continued to hold in the years of data collection. Estimates of occupied housing units by race and Hispanic origin from the 2003 American Community Survey also were used to project total occupied housing units in 2008, and the national vacancy rate (9%) was from the 2000 census.

Finally, as noted in the previous ''Calculation of screening amounts and sampling rates to achieve a self-weighting sample within each domain'' section, the expected examination response rates were set equal to achieved examination response rates by domain for earlier years of NHANES, and response rates for Mexican-American persons were used to estimate those for Hispanic persons. Screening requirements also varied from expectations depending on how much these earlier response rates differed from the actual experience in 2007–2010.

Sampling rate modifications for NHANES 2009–2010 sample

The NHANES 2007–2010 sample design included a number of sample design changes that resulted in a decrease in the number of examinations in some higher-responding domains, making the overall target number of examinations more difficult to reach than in previous surveys. These changes included: changing domain definitions and sample sizes for those aged 12–19; changing the domain definitions for oversampled minority adults; eliminating the supplemental sample of pregnant women; increasing the targeted number of examinations in the aged 20 and over domains; and combining Mexican-American persons and Hispanic persons into one oversampled domain.

In 2008, it appeared that the response rate patterns in this new design were such that the targeted 10,000 examinations would not be met for the 2007–2008 sample. Anticipating similar response rate patterns in the 2009–2010 sample, NCHS decided to marginally increase the target sample sizes in the low-income white-and-other domains to help achieve the average annual target sample sizes.

An additional target of 150 examinations in the annual samples for 2009 and 2010 were distributed among the sex-age low-income white-and-other domains using the most optimal method of allocation. For this method, an allocation factor was calculated such that the domain increase in the target number of examinations was proportional to the 2007–2008 response rate and inversely proportional to the domain sampling rate and the projected number of screenings required to obtain one examination. Considering all three factors helped to achieve maximum efficiency while reducing the variation in the base weights. The revised sampling rates for the low-income white-and-other domains are included in Table II (Appendix II).

Sample Selection Methods

Stratification and selection of PSUs

The operational requirements for NHANES are such that the amount of travel necessary for a sampled participant to visit a MEC should be minimized to increase the likelihood of achieving high response rates. As a result, individual counties were chosen as PSUs for NHANES. However, some counties have such small populations that their probabilities of selection would be lower than what is required to attain the sampling rates for some of the domains. If selected for the sample, they would introduce considerable variability into the weights. Consequently, these small counties were combined with one or more adjacent counties to form more efficient sampling units. For the same reason, independent cities in Virginia were combined with nearby counties.

The frame for NHANES 2007–2010 included all counties in the entire country. From the approximately 3,100 counties and county equivalents in the United States, 2,932 PSUs were formed (most of which consisted of individual counties), a sample of 60 study locations was selected, and 15 per year were randomly allocated to each of the years.

Calculation of PSU MOS

The NHANES sample was designed to yield a self-weighting sample for each sampling domain while producing an efficient workload in each study location. PSUs were selected with probabilities proportionate to an MOS. The selection probability of a PSU determines the maximum rate at which persons residing in that particular PSU can be selected.

The expression used to define the PSU MOS is similar to that used in previous years. The MOS of PSU h, denoted by M_h, is a weighted average of estimated populations by race and Hispanic origin and was calculated as

$$M_h = \Sigma_k A_k C_{hk}$$

and

$$A_k = \Sigma_l r_{kl} \frac{C^*_{.kl}}{C^*_{.k.}}$$

where

k = Race-Hispanic origin-income subdomain

l = Sex-age subdomain

C_{hk} = Most recent population estimate for race-Hispanic origin-income subdomain k in PSU h (see below)

r_{kl} = Sampling rate of persons in the (k,l)-th race-Hispanic origin-income-sex-age subdomain

$C^*_{.kl}$ = Most recent projection of the 2008 total population count for race-Hispanic origin-income-sex-age subdomain (k,l)

$C^*_{.k.}$ = Most recent projection of the 2008 total population count for race-Hispanic origin-income subdomain k

Because single counties, rather than larger areas made up of groups of counties, are optimal as NHANES PSUs, M_h was first calculated with h representing a single county.

At the time of PSU selection for the 2007–2010 PSUs, the most recent county-level estimates of population by race and Hispanic origin were from the 2003 U.S. Census Bureau population estimates. To obtain the estimates C_{hk}, these were adjusted by census 2000 county-level estimates of the proportion of the population not living in institutional group quarters in 2000, and estimates for white persons and others were split into low income and non-low income based on the census 2000 county-level estimates of the proportion of non-Hispanic white persons with a 1999 income below the poverty level.

The factors A_k (Table C) are the weights used to assign the relative contribution from each race-Hispanic origin group in the computation of MOS.

Table C. Values of A_k used in calculating primary sampling unit measures of size

Race and Hispanic origin	A_k
Hispanic	0.000249
Non-Hispanic black	0.000246
Non-Hispanic, low income, white and other	0.000186
Non-Hispanic, non-low income, white and other	0.000072

Minimum MOS

The selection probability of a PSU determines the maximum rate at which persons residing in that particular PSU can be selected for NHANES while retaining the self-weighting nature of the sample. If the MOS of a PSU is too small, the required sampling rates for some subdomains cannot be achieved. Consequently, special weighting procedures would be required for such PSUs, and the resulting variability in weights would increase sampling errors. To ensure that all required sampling rates could be achieved, counties with a very small MOS were combined with other adjacent counties.

The condition that determines the minimum MOS of a PSU is

$$P_h \geq \hat{r} \text{ for all } h$$

where

P_h = Probability of selecting PSU h

$\hat{r}$ = Maximum sampling rate among the sampling domains

For certainty PSUs, this condition always holds, because $\hat{r} \geq 1$ and $P_h = 1$. For noncertainty PSUs, the probability of selecting PSU h is

$$P_h = c_{NC} \frac{M_h}{\Sigma_{h \epsilon NC} M_h}$$

where

NC = Set of noncertainty counties

C_{NC} = Number of noncertainty PSUs to be selected

M_h = MOS for PSU h

Thus, the condition that determines the minimum MOS is equivalent to

$$M_h \geq \hat{r}_k \frac{\Sigma_{h \epsilon NC} M_h}{c_{NC}}$$

For each county, it was necessary to check whether the MOS of the county met the minimum MOS condition. Because the righthand side is a constant, the first step in this check was to compute this product. The number of noncertainty locations, c_{NC}, was 52.

The second term on the righthand side of the expression was found to be

$$\frac{\Sigma_{h \epsilon NC} M_h}{c_{NC}} = 612.6577$$

Based on this minimum MOS criterion, 204 counties were found to have an MOS that was too small. These counties were combined with neighboring noncertainty counties. The neighboring counties had to be adjacent, and the maximum distance between any two points in the combined-county area had to be less than 125 miles. Unless no alternatives met the aforementioned criteria, counties combined were also from the same state.

Fifty-seven counties were combined into PSUs that either consisted of three or more counties or had a maximum distance greater than 125 miles. To avoid the complexity of working with more than two county administrations and to reduce the listing and interviewing cost associated with traveling, the maps of these counties were reviewed and some were manually recombined. Two PSUs in Alaska with an MOS below the minimum MOS were not combined further because the distances were too great between them and the areas under consideration for combining.

After the necessary county combinations were made, the PSU MOS, M_h, was recalculated with h representing the combined counties as a single PSU.

Selection of certainty PSUs

Some counties had an MOS large enough that they were selected with certainty, and a few of these were selected multiple times. These certainty PSUs were removed from the county frame prior to noncertainty PSU selection.

A PSU was identified as a certainty if its weighted MOS exceeded 75% of the initial sampling interval; that is, PSU h was included in the sample with certainty if

$$M_h > 0.75 \frac{\sum_{h=1}^{H} M_h}{60}$$

where H is the number of PSUs on the entire sampling frame.

Some certainty PSUs were so large that they warranted more than one study location; otherwise, weighting factors would have to be applied to ensure appropriate representation, and these

weighting factors would reduce the efficiency of estimates. The number of study locations allocated to each certainty PSU was obtained by comparing the weighted MOS, M_h, for the PSU to the initial PSU sampling interval, $(1/60)\ \Sigma_{h=1}^{H} M_h$.

A total of 8 study locations in the full NHANES 2007–2010 out of the 60-location sample were assigned to certainty PSUs. These locations were in five counties; two counties contained multiple study locations.

Stratification

The stratification scheme for NHANES 2007–2010 PSUs was developed with the primary goal of efficiency for the 4-year sample and with the secondary goals of efficiency for 2-year and annual samples. For the 4-year sample, 13 major strata were defined based on geography and the metropolitan statistical area (MSA) status of the PSUs. Fifty-two minor strata were defined based on the demographics of the PSUs. Each major stratum included four minor strata, and one PSU was selected from each of these final strata.

The 4-year sample had a one-PSU-per-minor-stratum design; each annual sample had a one-PSU-per-major-stratum design. Two-year samples have a two-PSU-per-major-stratum design, with each PSU coming from different minor strata. These major strata were also used as the strata for variance estimation. However, because certainty PSUs are not selected within strata, variance strata for these PSUs are formed based on the size of the PSU relative to the other PSUs. As a result, some of these variance strata may have up to three PSUs for variance estimation depending on the number and size of the certainty locations that year. That is, all multiyear samples contained only one PSU per sampled minor stratum rather than multiple PSUs from the same stratum.

In forming the major strata, the variables used were census region (Northeast, Midwest, South, and West), MSA status, minority concentration, and the percentage of the population below the poverty level. The percentages of black persons and Hispanic persons in each PSU were obtained from the 2003 census population estimates. The percentage of white persons and others below poverty was based on the 2000 census, because more current data were unavailable. Table D contains descriptions of the PSUs within each major stratum.

The minor strata were constructed in such a way that they were equal in size to the extent possible (in terms of total MOS). The variables used to form the boundaries of the minor strata were minority concentration and the percentage of the population below the poverty level used in the formation of the major strata.

Table D. Description of major strata formed for selection of primary sampling units: National Health and Nutrition Examination Survey, 2007–2010

Major stratum	Description[1]
1	Nonmetropolitan Southern PSUs
2	Nonmetropolitan Northeastern, Western, and Midwestern PSUs
3	Metropolitan Northeastern PSUs with population less than 15.1% black and: – Less than 4.8% Hispanic; or, – More than 4.8% Hispanic and less than 5.8% white and other in poverty
4	Metropolitan Northeastern PSUs with population: – Less than 15.1% black, more than 4.8% Hispanic, and more than 5.8% white and other in poverty; or, – More than 15.1% black
5	Metropolitan Midwestern PSUs with population: – Less than 7% black; or, – More than 7% black, less than 7.6% Hispanic, and less than 6.4% white and other in poverty
6	Metropolitan Midwestern PSUs with population more than 7% black and: – Less than 7.6% Hispanic and more than 6.4% white and other in poverty; or, – More than 7.6% Hispanic
7	Metropolitan Southern PSUs with population less than 21.1% black and less than 6.6% white and other in poverty
8	Metropolitan Southern PSUs with population less than 21.1% black, and between 6.6% and 9.7% white and other in poverty
9	Metropolitan Southern PSUs with population: – Less than 21.1% black and more than 9.7% white and other in poverty; or, – Between 21.1% and 35.4% black, and less than 5.5% Hispanic
10	Metropolitan Southern PSUs with population: – Between 21.1% and 35.4% black, and more than 5.5% Hispanic; or, – More than 35.4% black
11	Metropolitan Western PSUs with population less than 9.3% black, less than 27.7% Hispanic, and less than 10% white and other in poverty
12	Metropolitan Western PSUs with population: – Less than 9.3% black, less than 27.7% Hispanic, and more than 10% white and other in poverty; or, – Less than 9.3% black, more than 27.7% Hispanic, and less than 8.5% white and other in poverty
13	Metropolitan Western PSUs with population: – Less than 9.3% black, more than 27.7% Hispanic, and more than 8.5% white and other in poverty; or, – More than 9.3% black

[1]Threshold values are approximate.

NOTE: PSU is primary sampling unit.

Selection of noncertainty PSUs

To improve the geographic distribution and diversity of the sample and to limit the burden imposed on any particular PSU over time, the NHANES 2007–2010 noncertainty PSUs were selected so as to minimize the number of PSUs that were in both the 2002–2006 and 2007–2010 samples. Note that the study locations in the NHANES 2002–2006 sample were selected as part of a larger sample intended for 2002–2007. Once it was determined that the data would be released every 2 years, as in 2003 with 2004 and 2005 with 2006, the locations intended to be fielded in 2007 were not visited. Even though persons in these locations were not visited, overlap with these locations was also minimized.

A number of methods were considered for minimizing the overlap between the 2002–2006 and 2007–2010 samples. The main criterion was that the method should be applicable to PPS samples with one unit selected per stratum. In addition, the method had to accommodate the change from Mexican-American to Hispanic sampling domains and the use of updated population estimates, the MOS, and stratification between the 2002–2006 and 2007–2010 samples. Ohlsson's method, the method found to best meet the needs of NHANES, uses permanent random numbers and exponential sampling to minimize overlap between two or more samples (11).

The first step in implementing Ohlsson's method was to retrospectively assign a number between 0 and 1, called a permanent random number (PRN), to each noncertainty county on the previous sampling frame. The value of the PRN depended on whether the county had been selected for the previous sample. The PRNs were then transferred to the corresponding counties on the 2007–2010 frame. Any noncertainty counties in the 2007–2010 frame that had been selected with certainty in the previous sample were randomly assigned a new PRN from the uniform distribution; see Ohlsson (11) for a complete description of retrospectively assigning PRNs.

To minimize overlap between the two samples, the PRNs were shifted by one-half; that is, the goal was to minimize the overlap only between two successive samples, 2002–2007 and 2007–2010. To minimize overlap between more than two samples, a PRN adjustment of less than one-half would be used. The PRNs were then transformed as

$$\xi_h = -\frac{\log(1 - X_h)}{p_h}$$

where

ξ_h = Transformed PRN for county h

X_h = Shifted PRN for county h; and

$$P_h = \frac{M_h}{\sum_{v \epsilon H_h} M_v} = \frac{\text{MOS of county } h}{\text{Total MOS of stratum } H \text{ containing county } h}$$

Next, the PSU in each stratum with the minimum transformed random number was selected for the NHANES 2007–2010 sample.

As a result of population changes and the switch from Mexican-American to Hispanic sampling domains between the previous NHANES frame and the 2007–2010 frame, the combination of counties not meeting the minimum MOS into PSUs was not identical. To have consistent sampling units across the two frames, counties were used as the sampling unit in Ohlsson's algorithm rather than PSUs. One exception was made for a PSU, consisting of two counties, that had been selected in the previous sample. Because Ohlsson's algorithm is restricted to one sampled unit per stratum, the PSU was treated as one unit in assigning the PRN and was therefore treated as one unit on the 2007–2010 frame. For 2007–2010, a PSU was selected if any counties in the PSU were selected. The selection probability for the PSU was the sum of the selection probabilities for the individual counties in the PSU.

The resulting sample consisted of one PSU from each stratum, with selection probabilities, P_h, proportional to the PSU MOS. In addition, as a result of the shifting of the PRN, the conditional probability of selecting a PSU for the 2007–2010 sample, given that it was selected for the previous sample, is less than if the samples had been selected independently.

Allocation of PSUs to time period

To have nationally representative annual samples (a design requirement of NHANES), study locations had to be assigned to years in a random fashion. One way to achieve nationally representative annual samples would be to select an independent sample of PSUs each year. This approach would lead to substantial overlap in PSUs each year and the overlap could lead to increased clustering of the sample, which would result in less precise estimates. In addition, each annual sample can have only 5,000 examined persons in 15 study locations. Therefore, a 4-year sample in NHANES was selected from a nested structure of major and minor strata. This stratification scheme was developed so that annual and multiyear samples were distributed evenly in terms of geography and certain population characteristics.

The certainty PSUs were sorted according to their MOS, and the noncertainty PSUs were sorted by major and minor strata. Within each major stratum, minor strata were paired. Each minor strata pair was randomly assigned to the study years 2 years apart. Assignment of the pairs to particular sets of study years and assignment of the study years within the pair were random within the first major stratum, and all other major strata followed the same pattern. Then one PSU was allocated from each major stratum each year.

The large certainty PSUs were assigned in a manner that appropriately reflected their relative size. For example, because one PSU was large enough to be selected with certainty in 3 years of the 4-year sample and contained three study locations within the 60-location sample for 2002–2007, one location was assigned to 3 years chosen randomly. In 1999, this PSU was divided into three study locations along tract boundaries: the northeastern, southern, and northwestern areas of the county. These locations have been and will continue to be fielded in that order. The next-largest PSU was selected with certainty in a 2-year sample and had two locations assigned; one of the study locations was randomly assigned to one of the first 2 years and the other to one of the second 2 years in a balanced fashion (2 years apart). Finally, the remaining three PSUs were selected with certainty in a 4-year sample but not in a 3-, 2-, or 1-year sample. The largest of the three was assigned to the year without the triple-location PSU, and the other two were assigned randomly.

Targeted number of sampled persons in each PSU

The initial target number of examined persons per location was 333, based on the assumption of a total of 5,000 examined persons per year in 15 study locations. Once the sample of locations was selected, the examination targets were adjusted. The final target number of examined persons for

certainty locations was obtained by adjusting this initial target by the relative size of the location. For certainty locations, this was calculated as the MOS allocated to the study location divided by the initial sampling interval used for selecting noncertainty PSUs, $(1/52)\ \Sigma_{h=1}^{H} M_h$. The relative size of certainty locations ranged from 0.689 to 0.995.

For all other noncertainty locations, the initial examination target was adjusted by the relative contribution of the location's stratum to the total noncertainty MOS. Finally, the target number of identified sampled participants for a given study location was derived from the desired number of examined persons by inflating that number to account for the predicted combined screener, interview, and examination response rate for the study location.

NHANES response rates (combined screener, interview, and examination) for each location in an annual sample were predicted using a linear regression based on the actual response rates and location-level characteristics of prior study locations. Prediction based on previous experience has proven more accurate than simply applying a single response rate across all study locations.

Each year, the model was refit with the most recent data available at the time of the prediction. A relatively large number of geographic, demographic, and economic variables from the U.S. Census Bureau were assembled and brought into a linear regression model as potential independent variables, with the study location response rate as the dependent variable. A stepwise regression was used. The final model for each year was decided based on a combination of the regression correlation coefficient and a statistic that adjusts for the total number of variables included in the model. The model was applied to the values of the selected variables for the current year's study locations to predict their response rates.

After these predicted response rates were reviewed with senior project staff, some of the rates were adjusted based on past experience. Once the response rate predictions were finalized, they were applied to the target number of examinations to predict the number of identified sampled participants that would be required in each study location to achieve the targets. This became the initial target number of identified sampled participants.

Selection of segments

The second stage of the design involved sampling segments within each PSU. Segments were selected as a continuous process about 5 to 6 months prior to the start of the field period for the study location.

The usual practice in area samples is to list all DUs in sampled segments and apply a prespecified sampling rate to the listed DUs. This approach gives all DUs the desired probabilities of selection. For example, if the sampling rate is 50%, then one-half of the DUs listed in the segments will be included in the sample. If the number of DUs has tripled due to new construction (i.e., housing units built since the most recent decennial census), the same sampling rate will produce three times as many interviews and examinations as the number originally expected. Such dramatic changes in the segment size are expected when the data collection period is several years after the most recent decennial census for which data files are available, as was the case for NHANES 2007–2010.

If the segment contains much new construction, the segment MOS may be inaccurate. As a result, either a larger-than-expected sample must be drawn from that segment or a weighting factor must be applied to all sampled participants from that segment. Because highly variable sample sizes are not operationally feasible for NHANES, subsampling within PSUs would be necessary to attain equal sample sizes across PSUs. However, this would require the application of a weighting factor, which would reduce the efficiency of the sample.

To update a sampling frame when the sample is to be selected with respect to an MOS, but a reliable estimate of the MOS is not available, double sampling (or two-phase sampling) can be used. This was executed in NHANES, by first having the home office and field staff determine the number of DUs in the larger-than-needed first-phase sample of segments through a combination of digital and windshield canvassing (1). Then, an updated MOS reflecting the ratio of the actual number of DUs to the expected number of DUs was calculated. The final sample of segments was selected by subsampling from the first-phase segments using the updated MOS.

Stratification within PSUs

The procedures for selecting the segment sample involve implicit stratification by minority density and geography. To keep combined blocks within a single block group, the stratification is based on characteristics of the block group in which segments are located. Within the geographical strata, implicit stratification is created by sorting the area segments by minority density, tract number, census-designated place, block group within tract, and segment number within block group, and selecting a systematic sample with PPS.

MOS of segments

The segment MOS calculation is similar to that for the PSU MOS. Prior research on intraclass correlations and unit costs indicated that an average of 14 examined sampled participants per segment was reasonably close to an optimum for most statistics in NHANES. As indicated earlier, operational requirements make it necessary to have a fairly constant number of examined sampled participants per study location, usually about 333. This implies having 24 segments per PSU.

Because segments consist of census blocks or groups of blocks, the segment MOS is a sum of MOSs calculated at the block level. In study locations that experienced significant growth between the 2000 decennial census and the segment selection, a two-phase sampling procedure was followed, with the segment MOS calculated separately for each phase.

For the first phase, let $M_{hb(1)}$ denote the MOS of block b in PSU h, so that

$$M_{hb(1)} = \Sigma_{k^*} A_{k^*} C_{hbk^*}$$

$$A_{k^*} = \sum_{l} r_{k^*l} \frac{C^*_{.k^*l}}{C^*_{.k^*.}}$$

where

h = PSU

b = Block

k^* = Race-Hispanic origin subdomain (non-Hispanic black, Hispanic, and white-and-other income levels combined)

C_{hbk^*} = 2000 population of race-Hispanic origin k^* in block b in PSU h

r_{k^*l} = Sampling rate of persons in the (k^*,l)-th race-Hispanic origin-sex-age subdomain

$C^*_{.k^*l}$ = Most recent projection of 2008 total population count for race-Hispanic origin-sex-age subdomain (k^*,l)

$C^*_{.k^*.}$ = Most recent projection of the year 2008 total population count for race-Hispanic origin subdomain k^*

For the non-Hispanic black and Hispanic subdomains, the factor A_{k^*} is the same as the A_k used in the PSU sampling MOS calculation described in the previous ''Calculation of PSU MOS'' section. Because income level is not available at the block level, the value for A_{k^*} for all non-Hispanic white persons and others was calculated as a weighted average of the A_k values used in the PSU sampling for low-income and non-low-income white persons and others. For the 2007–2008 sample, A_{k^*} for white and other persons was calculated as 0.000087. With the sampling rate increase for low-income white and other persons for 2009–2010, the value of A_{k^*} increased to 0.000092.

The MOS for the first-phase segments $j^{[1]}$ are the sums of the MOS of the block(s) comprising each segment. These MOSs are denoted by $M_{hj^{[1]}(1)}$.

The MOS used for the second-phase segment selection is the segment growth rate. Based on the DU counts obtained for the first-phase sample segments, the growth rate is estimated by computing the ratio of the actual number of DUs (counted as determined by home-office staff and field staff through a combination of digital and windshield canvassing) to the expected number of DUs in the segment (based on the 2000 decennial census data).

Let $U'_{hj^{[1]}}$ denote the number of DUs found by NHANES staff in the field for the first-phase segment $j^{[1]}$ in PSU h. The growth ($g_{hj^{[1]}}$) of the first-phase segment $j^{[1]}$ is estimated as:

$$g_{hj^{[1]}} = \frac{U'_{hj^{[1]}}}{U^{[0]}_{hj^{[1]}}}$$

where $U^{[0]}_{hj^{[1]}}$ is the number of DUs in segment $j^{[1]}$ according to the 2000 decennial census.

Thus, the second-phase MOS for segment $j^{[1]}$ selected in the first phase of sampling in PSU h is equal to

$$M_{hj^{[1]}(2)} = g_{hj^{[1]}}$$

Number of segments and probability of selection

As discussed in the previous ''Targeted number of sampled persons in each PSU'' section, the person sample sizes for some study locations selected with certainty were adjusted to account for their size relative to the other selected locations, to minimize the effects of intraclass correlation. The number of segments selected in the certainty locations was also adjusted from 24 to account for the relative size of the location. As a result, some study locations selected with certainty contained as few as 17 segments or as many as 24 segments in the second phase of segment sampling, denoted $n_{h(2)}$. To achieve proper within-segment sampling rates in study locations in which the segment sample was selected in two phases, the first-phase sample must be larger than the ultimate sample. In NHANES 2007–2010, more segments were selected than ultimately needed: 50 segments were selected in such locations in the first part of 2007, but this was increased to 100 in subsequent locations so that growth in any particular segment did not overwhelm the segment sample.

For each study location, the conditional probability of selection of first-phase segment $j^{[1]}$ is

$$P_{hj^{[1]}(1)} = \min\left[\frac{n_{h(1)} M_{hj^{[1]}(1)}}{\sum_{j^{[1]}=1}^{N_{h(1)}} M_{hj^{[1]}(1)}}, 1\right]$$

where

$N_{h(1)}$ = Total number of segments in first-phase segment frame in the h-th PSU

$n_{h(1)}$ = Total number of first-phase segments to be selected in the h-th PSU

$M_{hj^{[1]}(1)}$ = First-phase MOS of segment $j^{[1]}$ in the h-th PSU

Given the first-phase segments, the conditional selection probability of second-phase segment $j^{[2]}$ is

$$P_{hj^{[2]}(2)} = \min\left[\frac{n_{h(2)} M_{hj^{[2]}(2)}}{\sum_{j=1}^{n_{h(1)}} M_{hj^{[2]}(2)}}, 1\right]$$

where

$n_{h(2)}$ = Total number of second-phase segments to be selected in the h-th PSU

$M_{hj^{[2]}(2)}$ = Second-phase MOS of segment $j^{[2]}$ in the h-th PSU

The actual probability of selection of a segment depends on the MOS of the segment and the probability of selection of the location from which the segment is selected. So the overall probability of selection of a second-phase segment $j^{[2]}$ is

$$P_{hj^{[2]}(2)} P_{hj^{[1]}(1)} P_h = n_{h(2)} n_{h(1)} \left(\frac{M_{hj^{[2]}(2)}}{\sum_{j^{[2]}=1}^{n_{h(1)}} M_{hj^{[2]}(2)}}\right)\left(\frac{M_{hj^{[1]}(1)}}{\sum_{j^{[1]}=1}^{N_{h(1)}} M_{hj^{[1]}(1)}}\right) P_h \quad [1]$$

Note that in study locations that do not require the two-phase procedure, $n_{h(2)} = n_{h(1)} = n_h$. Moreover, in study locations where no second phase is needed, $M_{hj^{[2]}(2)} = 1$. Substituting into the second-phase probability of selection above results in:

$$P_{hj^{[2]}(2)} = \min\left(\frac{n_{h^*}(1)}{\sum_{j=1}^{n_h}(1)}, 1\right) = \min\left(\frac{n_h}{n_h}, 1\right) = 1$$

so that the segment probability of selection within one-phase locations is simply the first-phase probability of selection.

Minimum MOS of segments

One of the goals of the sample design is to create equal probabilities of selection for each domain within a study location. This enables the selection of a nearly within-domain self-weighting sample and facilitates the selection of persons. To create equal probabilities, the within-segment sampling rate for a domain in study locations selected without certainty should be

$$r_{hjkl} = \frac{r_{kl}}{P_h P_{hj^{[1]}(1)} P_{hj^{[2]}(2)}} \qquad [2]$$

For locations selected with certainty, $P_h = 1$, so that the within-segment sampling rate should be

$$r_{hjkl} = \frac{r_{kl}}{P_{hj^{[1]}(1)} P_{hj^{[2]}(2)}}$$

The within-segment rates must be less than or equal to 1. The most severe constraint is for domains with the highest value of r_{kl}. These maximum sampling rates are known as $\hat{r}$; that is,

$$\hat{r} = \max_{k,l} \{r_{kl}\}$$

Therefore,

$$\max_{k,l} \{r_{hjkl}\} = \frac{\hat{r}}{P_n P_{hj^{[1]}(1)} P_{hj^{[2]}(2)}} \le 1 \qquad [3]$$

Replacing the denominator in equation [3] with its equivalent in equation [1], the condition in equation [3] becomes

$$\frac{\hat{r}}{n_{h(2)} n_{h(1)} \left(\frac{M_{hj^{[2]}(2)}}{\sum_{j^{[2]}=1}^{n_{h(1)}} M_{hj^{[2]}(2)}} \right) \left(\frac{M_{hj^{[1]}(1)}}{\sum_{j^{[1]}=1}^{N_{h(1)}} M_{hj^{[1]}(1)}} \right) P_h} \le 1$$

which is equivalent to

$$M_{hj^{[1]}(1)} \ge \left(\frac{\hat{r}}{P_h \frac{n_{h(2)}}{\sum_{j_{[1]}=1}^{N_{h(1)}} M_{hj^{[1]}(1)}}} \right) \bullet \left(\frac{\sum_{j_{[2]}=1}^{n_{h(1)}} M_{hj^{[2]}(2)}}{n_{h(1)} M_{hj^{[2]}(2)}} \right) \qquad [4]$$

Consequently, the first-phase minimum MOS is a product of two factors. The first factor was calculated for the study location based on known information. The second factor is based on the second-phase MOS, which was not known at the time of selection of the first-phase segments.

For study locations that do not require the two-phase process, the second factor reduces to 1:

$$\frac{\sum_{j^{[2]}=1}^{n_{h(1)}} M_{hj^{[2]}(2)}}{n_{h(1)} M_{hj^{[2]}(2)}} \quad \frac{\sum_{j^{[2]}=1}^{n_h} 1}{n_{h*1}} = \frac{n_h}{n_h} = 1$$

and equation [4] reduces to

$$M_{hj^{[1]}(1)} \ge \frac{\hat{r}}{P_h \frac{n_h}{\sum_{j^{[1]}=1}^{N_{h(1)}} M_{hj^{[1]}(1)}}} \qquad [5]$$

the minimum MOS for segments.

For study locations where the full two-phase process was implemented, $M_{hj^{[2]}(2)}$ was not known when the first-phase segment was selected. In this case, the second factor must be considered as

$$\frac{\sum_{j=1}^{n_{h(1)}} M_{hj^{[2]}(2)}}{n_{h(1)} M_{hj^{[2]}(2)}} = \frac{ave(M_{hj^{[2]}(2)})}{M_{hj^{[2]}(2)}}$$

This factor would inflate the minimum MOS to account for expected growth in the segment due to new construction. Because the actual values are not known, an inflation factor constant across all segments was used. Based on empirical research, this inflation factor was set at 1.25.

In implementing the sample selection, the minimum MOS was made 50% greater than needed in 2007 through mid-2008 to attain the maximum sampling rates $\hat{r}$. In mid-2008, this was increased to 80% given the length of time since the last decennial census. As a result, the minimum MOS was increased to permit the selection of reserve 50% and 80% samples, in the respective time frames.

Within each PSU, the blocks reported on the block-level census files were sorted by minority density, tract, census-designated place, block group, and block number. Blocks with MOS below the minimum were combined with succeeding blocks until the desired measure was achieved. To the extent possible, the combinations were kept to the same block group. When the combinations came to the end of a block group without reaching the minimum, earlier blocks within the same block group were added. When necessary, blocks were combined across block groups within the same tract to form segments; however, collapsing blocks across tracts was not permitted. Consequently, the combinations consisted of blocks in close geographic proximity, and, in most cases, they were adjacent blocks. As a result of the method of combination, some large blocks that could have been segments by themselves were combined with small blocks.

At the second phase of segment selection, the constraint in equation [4] is equivalent to

$$M_{hj^{[2]}(2)} \ge \frac{\hat{r}}{P_h P_{hj^{[1]}(1)} \frac{n_{h(2)}}{n_{h(1)} \sum_{j^{[2]}=1} M_{hj^{[2]}(2)}}} \qquad [6]$$

The right side of equation [6] is the minimum MOS for the second-phase segment selection. Any first-phase segments, $j^{[1]}$, with MOS less than the minimum second-phase MOS are combined with adjacent segments to form the second-phase segments, $j^{[2]}$, prior to selection.

After second-phase selection, any $j^{[2]}$ segments that had been formed as a combination of first-phase segments to achieve the second-phase minimum MOS were disaggregated into their first-phase components for operational reasons. The within-PSU probability of selection was equal for the constituent segments. After completing the segment selection, the selected segments are denoted by j (with the superscript dropped) to simplify the notation.

Controlling sample size per PSU

Screening and interviewing begin approximately 3 weeks before the first examinations in a location. This ensures that there are enough identified and interviewed sampled participants to fill available examination sessions. Once the MEC team arrives at a location (after conducting examinations in a previous location only days before), examinations for interviewed sampled participants begin. Examinations continue for approximately 5 weeks. After the last examination day, the field staff has limited time to travel to the next study location.

This strict time schedule for examining the sampled participants in each study location necessitates the advance establishment of a fixed screening and examination workload in each location (see ''Operational Requirements'' in the previous ''Design Specifications'' section). However, as with any survey, it is not possible to predict the exact number of screened households that will supply the desired number of sampled participants and completed examinations. This is further aggravated by variations in response rates from location to location.

A fixed number of sampled participants is expected in the locations selected without certainty as a result of the constant sampling rate defined for each domain across all study locations, r_{kl}. Within the study location, the sampling rate used for domain (k,l) is

$$P_{hj}\frac{\hat{r}}{P_h P_{hj}}\frac{r_{kl}}{\hat{r}} = \frac{r_{kl}}{P_h}$$

It can be shown that $\frac{r_{kl}}{P_h}$ is constant across the locations selected without certainty to the extent that the population distribution is approximately the same as that in the decennial census data. Therefore, the number of sampled participants is approximately constant across these locations.

Because the number of segments per location is constant (i.e., 24) for all but the certainty PSUs, the variation in quotas per location is also reflected in segment sample sizes. In addition, the changes in the population distribution since the most recent census are likely to be greater among segments than among locations. The average segment size is thus expected to vary more than the average location size, but even this variation will generally be within a moderate range.

The approximate equality that exists in participant-level sample sizes per location and segment does not occur in the screening sample. The amount of screening in a location is partially based on what proportion of the location population lives in high-density strata. The amount of screening per segment will vary considerably among the density strata. Consequently, it is necessary to use a procedure that can produce samples either somewhat larger or somewhat smaller than those arising from application of the self-weighting sampling rates; see the ''Selection of sample persons'' section below for more information on this procedure.

Selection of DUs and persons

The third stage of sample selection consisted of DUs, including certain types of group quarters. All DUs in the sample segments were listed, and a subsample of DUs was designated for screening to identify potential sample persons for interviews and examinations. The subsampling rates were designed to produce a national, approximately equal, probability sample of DUs in most of the 50 states. Within each geographical stratum, there was an approximately equal probability sample of DUs across all PSUs.

Within-segment sampling rates

Within segments, DUs were selected with equal probability at a rate equal to the maximum within-segment sampling rate required to attain the subdomain sampling rates. That is, the sampling rate used to select DUs within segment j in PSU h is

$$\frac{\max\limits_{k,l}\{r_{kl}\}}{P_h P_{hj}}$$

Sampled participants were selected within DUs using the ratio of the subdomain sampling rate to the maximum subdomain sampling rate. Thus, the overall selection probability for a person in race-Hispanic origin-sex-age-income subdomain (k,l) is

Pr{select PSU h}. Pr{select segment hj | select PSU h}

Pr{select a DU in segment hj | select segment hj}

Pr{domain (kl) flagged for selection in the DU | the DU in segment hj selected}

$$= P_h \cdot P_{hj} \cdot \frac{\max\limits_{k,l}\{r_{kl}\}}{P_h \cdot P_{hj}} \cdot \frac{r_{kl}}{\max\limits_{k,l}\{r_{kl}\}} = r_{kl}$$

and it can easily be shown that these probabilities yield approximately equal sample sizes for each PSU.

Selection of sample persons

The fourth stage of sample selection consisted of selecting sample persons. Once the DU sample was released to the field, each DU was screened to determine whether it was occupied, vacant, or for seasonal use only. Only occupied DUs, or households, were eligible. Once the sampled households were identified, a sample of persons to be interviewed and examined from each individual household was selected. All eligible members within a household were listed, and a subsample of persons was selected based on sex, age, race and Hispanic origin, and income. Sampled participants were selected at rates established to ensure that the target sample sizes by subdomain were achieved, and the average number of sampled participants per household was maximized.

Considerable subsampling was needed to reduce the screening sample of households to the desired number of sample participants. If independent random or systematic selections had been made for the subdomains, in most cases only one person in a household would have been selected, and the average sample size per household would have been quite low, not much above one.

A method of subsampling was used to maximize the number of sampled participants per household. (Conversely, this method minimizes the number of households containing sampled participants.) The effect of within-household clustering is not a large

concern for NHANES, because most analyses are done within subdomains, and there is generally little within-household clustering at the subdomain level.

The method begins with the designated screening sample from which persons are to be subsampled. The persons are classified into Q subdomains with sampling rates r_1, r_2, ... r_Q. The subdomains are ordered by subsampling rate so that $r_q \leq r_{q+1}$. Note that the screening rates are set so that $r_Q = 1$; that is, the screening rate is equal to the maximum subsampling rate.

The set of households designated for screening is partitioned into L unequally sized random subsets, such that the sizes of the subsets are proportionate to r_1, $r_{(2)} - r_{(1)}$, $r_{(3)} - r_{(2)}$, ..., $r_{(q+1)} - r_{(q)}$, $r_Q - r_{(Q-1)}$. It is clear that the sum of these proportions is equal to $r_Q = 1$, so that each screened household is assigned to exactly one of the sets.

This sampling procedure was implemented using a set of sampling flags that designate for each DU which domains were eligible for sampling. The interviewers were not required to carry out any subsampling operation. They were instead instructed by the automated system (based on the set of domain flags provided for each household) which persons to include as sampled participants. Note that because the sampling domain flags were prepared in advance of the screening, they were based on the expected distribution of the screened sample by race and Hispanic origin, sex, age, and income, rather than on the distribution actually achieved. Thus, this procedure was expected to produce small deviations in the sample from the desired number in each domain. Such deviations are inevitable when subsampling rates must be established before the screening is completed.

The subsampling is then carried out as follows:

- In the first random subset of households (corresponding to 100* r_1% of all screened households), all persons in the household are designated as sampled participants.
- In the second random subset of households [corresponding to 100* $(r_{(2)} - r_{(1)})$% of all screened households], all persons in the household are sampled participants except those in subdomain 1; therefore, those persons in subdomain 1 are selected only in the first random subset, with probability r_1.
- In the third random subset of households, all persons in the household are sampled participants except those in subdomains 1 and 2. Thus, those in subdomain 2 are selected only in the first two random subsets, with probability $r_1 + (r_{(2)} - r_{(1)}) = r_{(2)}$.
- This procedure is continued in this manner through the Q-th random subset, for which only persons in subdomain Q are sampled participants.

Instead of unrestricted randomization, a pseudorandom procedure was used to guarantee that all sampled DUs within each sequence of 100 consecutive DUs were assigned different random numbers (because the random number assigned determined the set of domains to be selected). To start, a random number between 0.00 and 0.99 was assigned to the first DU, with a separate initial random number used in each study location. The number 0.41 was then used as a skip interval and added successively to obtain the random number for the next case. The random number was then used, in the manner described above, to determine the sampling domain flags assigned to each case.

Initially, a screening sample was drawn for each study location using sampling rates larger than those required to attain the target sample sizes in each domain. Each study location's screening sample was then divided into release groups. Each group was a systematic subsample of the screening sample, with the screening sample sequenced by segment number and a temporary, geographically based sequence number prior to subsampling. Thus, each release group contained cases from all segments, except as limited by release group and segment size. In 2007, the reserve sample selected was 50% larger than required. To guard against any shortfall caused by using data nearly a decade old to select segments, the size of the reserve was increased to be 80% larger than required midway through fielding the 2008 study locations. Table E gives the expected distribution of the sample of DUs across release groups.

In most study locations, the first, and largest, release group (i.e., group A) was released to the interviewers initially. The yield from this group was monitored and used to project estimates of the total yield of sampled participants expected from this group. Based on these figures, additional groups (or portions of groups) were released as needed. The sample was monitored on a daily basis to determine whether

Table E. Release group distribution: National Health and Nutrition Examination Survey, 2007–2010

2007–Mid-2008		Mid-2008–2010	
Release group	Percentage for 150% sample	Release group	Percentage for 180% sample
A	50	A	42
B	10	B	8
C	8	C	7
D	8	D	7
E	6	E	6
F	6	F	6
G	3	G	5
H	3	H	4
I	2	I	4
J	2	J	3
K	1	K	3
Z	1	L	2
. . .	. . .	M	2
. . .	. . .	N	1

. . . Category not applicable.

additional release groups were required. The cases in group Z of the 50% reserve sample had sampling flags indicating that all persons in the household should be sampled; it was designed to be used as a last resort, only when the sample yield in a study location was low after all other groups had been released. Because this release group was never utilized in any location since the beginning of the continuous NHANES in 1999, such a subsample was not included after the transition to an 80% reserve.

Special Samples

Examination session subsamples

NHANES has two examination session subsamples: the morning subsample, and the afternoon or evening subsample. Sampled participants selected for the morning sessions were instructed to fast overnight; those selected for the afternoon or evening sessions were also instructed to fast, but for a shorter period of time. Data that are sensitive to fasting times should be analyzed separately for these two groups.

Because it is generally more convenient for household members to come to the MEC at the same time (and this is believed to favorably affect response rates), the examination session subsample assignment was made at the household level. The assignment was based on the household identifier (ID). If the household ID was an even number, the household was assigned to the morning subsample; if the household ID was an odd number, the household was assigned to the afternoon or evening subsample. The examination session subsample was assigned immediately after DUs were selected.

Although the examination session subsamples were designed to be approximately half-samples, some deviations resulted. Additionally, sampled participants did not always report to the assigned examination session. For example, some sampled participants assigned to be examined in a morning session may have been unable to report to the MEC at that time; in such cases, they were permitted to schedule afternoon or evening examinations.

Examination and laboratory subsamples

The examination component of NHANES consisted of physical, dental, and laboratory tests to assess various aspects of health. For some of these components, subsampling was required to reduce respondent burden and facilitate the scheduling and completion of examinations.

Sampled participants were assigned to laboratory subsamples by first using an algorithm to randomly divide them into 12 groups; combinations of these groups were predetermined to create the various subsamples. Subsamples are most often mutually exclusive. In rare cases, subsamples overlap with one another but not completely; for example, the persons who are part of a 1/3 environmental subsample may also be found in the 1/2 fasting subsample. To combine the 1/3 environmental subsample with the 1/2 fasting subsample, new weights would need to be created by the researcher because they have not been created by NCHS. Sample sizes may get quite small when combining these subsamples, resulting in unstable and unreliable statistical estimates.

After subsample assignment, weighting factors were attached to each sampled participant record, as appropriate, to reflect this stage of subsampling. Table III (Appendix II) provides the specifications for the components requiring subsampling.

As stated previously, more information about the 2007–2010 estimation procedures, the creation of weights for the entire sample and subsamples, and appropriate variance estimation methods to be used when analyzing NHANES data can be found in ‘‘National Health and Nutrition Examination Survey: Estimation Procedures, 2007–2010.’’

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Appendix I. 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 specific demographic groups. For NHANES, sampling domains are defined by race and Hispanic origin, income, age, and sex. See also *Sampling domain*.

Domain flags—See *Sampling domain flags*.

Double sampling—A general term for a method used in a number of statistical applications, such as stratification and regression, or ratio estimation. One of the applications of double sampling is to update a sampling frame when the sample is to be selected with respect to a measure of size (MOS), but a reliable estimate of that MOS is not available. For NHANES, double sampling, or two-phase sampling, was used in second-stage units (SSUs, or segments) late in a decade when population counts from the U.S. Census Bureau—used in calculating MOS—were old and potentially no longer representative of the study location. In the NHANES study locations for which an accurate MOS was not available, a larger-than-needed sample of segments was selected in the first phase. After field staff determined the number of dwelling units (DUs) in the first-phase sample of segments, an updated MOS that reflected the ratio of the actual number of DUs to the expected number of DUs was calculated. The final sample of segments was selected by subsampling from the first-phase segments using the updated MOS.

Dwelling unit (DU), housing unit—The 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 could 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 institutional settings, such as correctional facilities, nursing and skilled nursing facilities, inpatient hospice facilities, mental health or psychiatric hospitals, 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 institutional settings. These include college or university housing, group homes intended for adults, residential treatment facilities for adults, workers' group living quarters and 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.

Low income—Beginning in 2000, NHANES split the sampling domains for white and other persons based on their income status into low income and non-low income. Low-income persons are those at or below 130% of the federal poverty level. The poverty threshold used in this determination was based on the most recent poverty guidelines published by the U.S. Department of Health and Human Services (HHS); these thresholds are updated annually by the U.S. Census Bureau.

Maximum sampling rate—The largest probability of selection assigned to a demographic group within a survey design. This value within certain strata and demographic groups was used in determining the sample size and other sampling parameters in NHANES.

Measure of size (MOS)—A value assigned to every sampling unit in a sample selection, usually a count of units associated with the elements to be selected. For NHANES, the MOS is actually a weighted average of estimates of population counts for the race-Hispanic origin-income groups of interest.

National Center for Health Statistics (NCHS)—The nation's principal health statistics agency, which 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 HHS.

Noninstitutional group quarters—See listing under *Group quarters*.

Noninstitutionalized civilian population—Includes all people living in households and excludes 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 have such a large MOS that they are selected into the survey with a probability of one. These are referred to as PSUs selected with certainty, or ''certainty PSUs''; all other PSUs are selected without certainty, known as ''noncertainty PSUs.''

Probability proportionate to size (PPS) sampling—In this method, the probability of selecting any unit varies with the size of the unit, giving larger units a greater probability of selection and smaller units a lower probability. NHANES uses PPS sampling in the selection of PSUs and SSUs.

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 the respondents' identities are protected. NCHS disseminates this file to encourage widespread use of the survey data.

Race and Hispanic origin—The term used in this report as it was used in NHANES sample selection, covering three groups: Hispanic persons, non-Hispanic black persons, and a third group consisting of all other persons.

Release group—A systematic subsample of a study location's screening sample, with the screening sample sequenced by segment number and a temporary, geographically based sequence number. Each release group contained cases from all segments, except as limited by release group and segment size. In most study locations, the 50 percent release group (i.e., group A) was released to the interviewers first. The yield from this group was monitored and used to project estimates of the total yield of sample persons expected from this group. Based on these figures, additional groups (or portions of groups) were released as needed. The sample was monitored daily to determine whether additional release groups were required.

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 interviews are ''interview respondents.'' Persons agreeing to complete the in-home interviews and an examination at 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. 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. These special data sets are for (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 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; these could be on either the full sample or a special subsample.

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

Sampling domain—NHANES 2007–2010 includes 72 sampling domains, and Table B in this report contains the specific sampling domains for those years. See *Domain*.

Sampling domain flags—Strings of zeroes and ones attached to each sampled DU in the computer-assisted personal interview system. Each race-Hispanic origin-income group comprised one string, with each digit of the string representing one of the specific age-sex sampling domains. If the digit corresponding to an age-sex domain in a race-Hispanic origin string contained a 1, then all persons in that DU with matching demographic characteristics were included in the sample. The zeroes and ones in each string were set based on the sampling rates.

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-sex-age-income 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, or screening interview, 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 members. In NHANES, only persons aged 18 and over can answer the screener.

Screening—The process of conducting, or attempting to conduct, the screening interview in the DUs contained in the groups released. Occupied DUs (households) are screened through the screening interview. Other units can also be screened; the process for these units is verification that they are either vacant or not DUs. See *Screener*.

Screening sample—The sample of DUs selected for a study location.

Secondary sampling unit (SSU)—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. The selection of segments comprises the second stage of sampling. Within each segment, a sample of DUs was selected.

Self-weighting sample—A sample for which each elementary unit in the population has the same, nonzero chance of selection into the sample; that is, they are selected with the same constant probability. Higher-stage sampling units may be selected with differing probabilities, but such differences in selection probabilities at various stages cancel out. NHANES is a self-weighting sample of persons within each sampling domain.

Simple random sample—A sample in which all members of the population are selected directly and have an equal chance to be selected for the sample. The NHANES sample is not a simple random sample. The NHANES sample was stratified, was selected in stages, and employed unequal chances of selection for the respondents by race and Hispanic origin, income, age, and sex. Such designs are referred to as ''complex'' and require special software to estimate the variance of statistics computed from a sample with a complex design.

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. For the selection of PSUs fielded in 2007–2010, PSUs were stratified based on region, metropolitan statistical area status, and various population demographics.

Study location—The set of segments within a PSU that were fielded together, with all MEC examinations conducted at the same physical location. The distinction between a PSU and a study location is necessary because some large certainty PSUs were divided into multiple study locations and fielded at different times.

Target population—The population to be described by estimates from the survey. In NHANES, the target population is the resident civilian noninstitutionalized population of the United States, which 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 persons residing outside the 50 states and the District of Columbia.

Two-phase segment selection—See *Double sampling*.

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, which may underestimate the sampling variance because they do not incorporate any effects of having taken a sample compared with collecting data from every person in the full population. Estimating the variance in NHANES requires special statistical software, as discussed in this report.

Weight—See *Sample weight.*

Appendix II. Supporting Tables and Figure

Table I. Derivation of expected screening requirements: National Health and Nutrition Examination Survey, 2007–2010

Race and Hispanic origin-income-sex-age sampling domain[1]	Projected population in 2008	Target number of examinations for 1 year	Projected number of households screened to have one examined person	Projected number of households screened to attain target number of examinations over 4 years in self-weighting area sample	Projected number of examined persons in basic area sample	Number of additional examined persons needed to attain target
Non-Hispanic black						
Male and female:						
Under age 1	719,185	50	169	33,862	200	0
1–2	1,396,763	85	90	30,705	340	0
3–5	1,993,139	85	67	22,787	340	0
Male:						
6–11	1,861,369	85	70	23,790	340	0
12–19	2,639,626	92	48	17,832	368	0
20–39	4,836,058	105	30	12,638	420	0
40–49	2,388,683	53	65	13,657	210	0
50–59	1,993,381	53	78	16,365	210	0
60 and over	1,833,520	105	99	41,659	420	0
Female:						
6–11	1,812,239	85	73	24,744	340	0
12–19	2,650,667	85	48	16,354	340	0
20–39	5,771,249	105	25	10,313	420	0
40–49	2,914,677	53	52	10,848	210	0
50–59	2,434,324	53	62	12,989	210	0
60 and over	2,721,468	105	67	28,172	420	0
Hispanic						
Male and female:						
Under age 1	956,023	104	128	46,000	359	57
1–2	1,876,390	100	70	27,896	400	0
3–5	2,719,343	100	47	18,907	400	0
Male:						
6–11	2,517,646	100	53	21,131	400	0
12–19	3,239,835	102	39	16,067	408	0
20–39	7,669,437	140	18	10,022	560	0
40–49	2,959,450	70	48	13,526	280	0
50–59	1,831,538	70	78	21,856	280	0
60 and over	1,625,133	150	93	56,050	492	108
Female:						
6–11	2,422,751	100	54	21,525	400	0
12–19	3,096,683	102	40	16,489	408	0
20–39	7,083,806	140	19	10,870	560	0
40–49	2,862,243	70	48	13,493	280	0
50–59	1,921,269	70	72	20,102	280	0
60 and over	2,083,573	147	74	43,620	588	0
Non-Hispanic white and other, low income						
Male and female:						
Under age 1	456,475	45	266	46,000	173	7
1–2	853,105	54	139	30,090	216	0
3–5	1,247,951	54	97	21,053	216	0
Male:						
6–11	1,105,432	27	118	12,720	108	0
12–19	1,559,851	27	83	8,968	108	0
20–29	1,916,727	31	70	8,689	124	0
30–39	1,253,152	31	123	15,198	124	0
40–49	1,389,294	31	95	11,792	124	0
50–59	1,245,643	31	116	14,418	124	0
60–69	1,017,338	31	137	17,001	124	0
70–79	642,642	31	253	31,339	124	0
80 and over	436,802	20	417	33,395	80	0

See footnotes at end of table.

Table I. Derivation of expected screening requirements: National Health and Nutrition Examination Survey, 2007–2010—Con.

Race and Hispanic origin-income-sex-age sampling domain[1]	Projected population in 2008	Target number of examinations for 1 year	Projected number of households screened to have one examined person	Projected number of households screened to attain target number of examinations over 4 years in self-weighting area sample	Projected number of examined persons in basic area sample	Number of additional examined persons needed to attain target
Non-Hispanic white and other, low income—Con.						
Female:						
6–11	1,100,696	27	114	12,334	108	0
12–19	1,537,174	27	80	8,661	108	0
20–29	2,749,535	31	50	6,211	124	0
30–39	1,705,231	31	76	9,427	124	0
40–49	1,526,726	31	85	10,582	124	0
50–59	1,485,365	31	92	11,395	124	0
60–69	1,525,604	31	102	12,608	124	0
70–79	1,339,664	31	121	14,998	124	0
80 and over	1,466,528	31	139	17,265	124	0
Non-Hispanic white and other, non-low income						
Male and female:						
Under age 1	2,130,918	70	61	17,121	280	0
1–2	4,305,315	70	33	9,178	280	0
3–5	6,464,103	70	23	6,326	280	0
Male:						
6–11	6,686,619	70	24	6,607	280	0
12–19	9,656,681	71	15	4,205	284	0
20–29	11,868,349	79	13	4,139	316	0
30–39	12,116,185	81	14	4,662	324	0
40–49	14,702,605	82	11	3,663	328	0
50–59	14,261,362	79	13	3,975	316	0
60–69	9,403,249	80	19	5,927	320	0
70–79	5,198,607	79	31	9,877	316	0
80 and over	2,813,405	70	66	18,345	280	0
Female:						
6–11	6,314,206	70	23	6,366	280	0
12–19	9,186,595	68	15	4,150	272	0
20–29	11,181,398	75	14	4,053	300	0
30–39	11,997,292	79	13	4,215	316	0
40–49	14,954,947	79	11	3,438	316	0
50–59	14,638,075	75	11	3,362	300	0
60–69	9,840,533	72	18	5,096	288	0
70–79	5,931,088	67	34	9,230	268	0
80 and over	4,094,525	68	50	13,662	272	0
Total	298,138,462	5,000	. . .	. . .	19,829	164

. . . Category not applicable.

[1]Age in years.

Table II. Final sampling rates and base weights: National Health and Nutrition Examination Survey, 2007–2010

Race and Hispanic origin-income-sex-age sampling domain[1]	2007–2008		2009–2010[2]	
	Numerator of sampling rate[3]	Base weight	Numerator of sampling rate[3]	Base weight
Non-Hispanic black				
Male and female:				
Under age 1	0.74	2,197.71	0.74	2,197.71
1–2	0.67	2,423.66	0.67	2,423.66
3–5	0.50	3,265.82	0.50	3,265.82
Male:				
6–11	0.52	3,128.20	0.52	3,128.20
12–19	0.39	4,173.43	0.39	4,173.43
20–39	0.27	5,888.48	0.27	5,888.48
40–49	0.30	5,449.23	0.30	5,449.23
50–59	0.36	4,547.44	0.36	4,547.44
60 and over	0.91	1,786.37	0.91	1,786.37
Female:				
6–11	0.54	3,007.61	0.54	3,007.61
12–19	0.36	4,550.57	0.36	4,550.57
20–39	0.22	7,215.89	0.22	7,215.89
40–49	0.24	6,860.13	0.24	6,860.13
50–59	0.28	5,729.55	0.28	5,729.55
60 and over	0.61	2,641.55	0.61	2,641.55
Hispanic				
Male and female:				
Under age 1	1.00	1,617.80	1.00	1,617.80
1–2	0.61	2,667.76	0.61	2,667.76
3–5	0.41	3,936.02	0.41	3,936.02
Male:				
6–11	0.46	3,521.77	0.46	3,521.77
12–19	0.35	4,631.85	0.35	4,631.85
20–39	0.22	7,425.66	0.22	7,425.66
40–49	0.29	5,501.76	0.29	5,501.76
50–59	0.48	3,404.92	0.48	3,404.92
60 and over	1.00	1,617.80	1.00	1,617.80
Female:				
6–11	0.47	3,457.27	0.47	3,457.27
12–19	0.36	4,513.21	0.36	4,513.21
20–39	0.24	6,845.99	0.24	6,845.99
40–49	0.29	5,515.27	0.29	5,515.27
50–59	0.44	3,702.10	0.44	3,702.10
60 and over	0.95	1,706.07	0.95	1,706.07
Non-Hispanic white and other, low income				
Male and female:				
Under age 1	1.00	1,617.80	1.00	1,617.80
1–2	0.65	2,473.22	0.68	2,384.89
3–5	0.46	3,534.90	0.49	3,291.11
Male:				
6–11	0.28	5,850.60	0.34	4,786.85
12–19	0.19	8,298.50	0.29	5,601.49
20–29	0.19	8,564.47	0.27	6,034.06
30–39	0.33	4,896.73	0.38	4,216.63
40–49	0.26	6,310.83	0.31	5,148.31
50–59	0.31	5,161.38	0.36	4,444.52
60–69	0.37	4,377.29	0.41	3,991.06
70–79	0.68	2,374.67	0.70	2,300.46
80 and over	0.73	2,228.42	0.73	2,228.42

See footnotes at end of table.

Table II. Final sampling rates and base weights: National Health and Nutrition Examination Survey, 2007–2010—Con.

Race and Hispanic origin-income-sex-age sampling domain[1]	2007–2008		2009–2010[2]	
	Numerator of sampling rate[3]	Base weight	Numerator of sampling rate[3]	Base weight
Non-Hispanic white and other, low income—Con.				
Female:				
6–11	0.27	6,033.45	0.33	4,936.46
12–19	0.19	8,592.04	0.28	5,799.63
20–29	0.14	11,981.17	0.24	6,632.44
30–39	0.20	7,894.48	0.30	5,438.42
40–49	0.23	7,032.79	0.31	5,190.87
50–59	0.25	6,530.81	0.30	5,327.77
60–69	0.27	5,902.28	0.33	4,945.16
70–79	0.33	4,961.80	0.38	4,272.66
80 and over	0.38	4,310.49	0.40	4,049.25
Non-Hispanic white and other, non-low income				
Male and female:				
Under age 1	0.37	4,346.57	0.37	4,346.57
1–2	0.20	8,108.34	0.20	8,108.34
3–5	0.14	11,763.13	0.14	11,763.13
Male:				
6–11	0.14	11,263.77	0.14	11,263.77
12–19	0.09	17,699.38	0.09	17,699.38
20–29	0.09	17,977.79	0.09	17,977.79
30–39	0.10	15,962.95	0.10	15,962.95
40–49	0.08	20,314.70	0.08	20,314.70
50–59	0.09	18,720.29	0.09	18,720.29
60–69	0.13	12,555.30	0.13	12,555.30
70–79	0.21	7,534.69	0.21	7,534.69
80 and over	0.40	4,056.66	0.40	4,056.66
Female:				
6–11	0.14	11,690.30	0.14	11,690.30
12–19	0.09	17,930.75	0.09	17,930.75
20–29	0.09	18,359.86	0.09	18,359.86
30–39	0.09	17,654.24	0.09	17,654.24
40–49	0.07	21,643.66	0.07	21,643.66
50–59	0.07	22,132.77	0.07	22,132.77
60–69	0.11	14,603.62	0.11	14,603.62
70–79	0.20	8,063.03	0.20	8,063.03
80 and over	0.30	5,447.32	0.30	5,447.32

[1]Age in years.

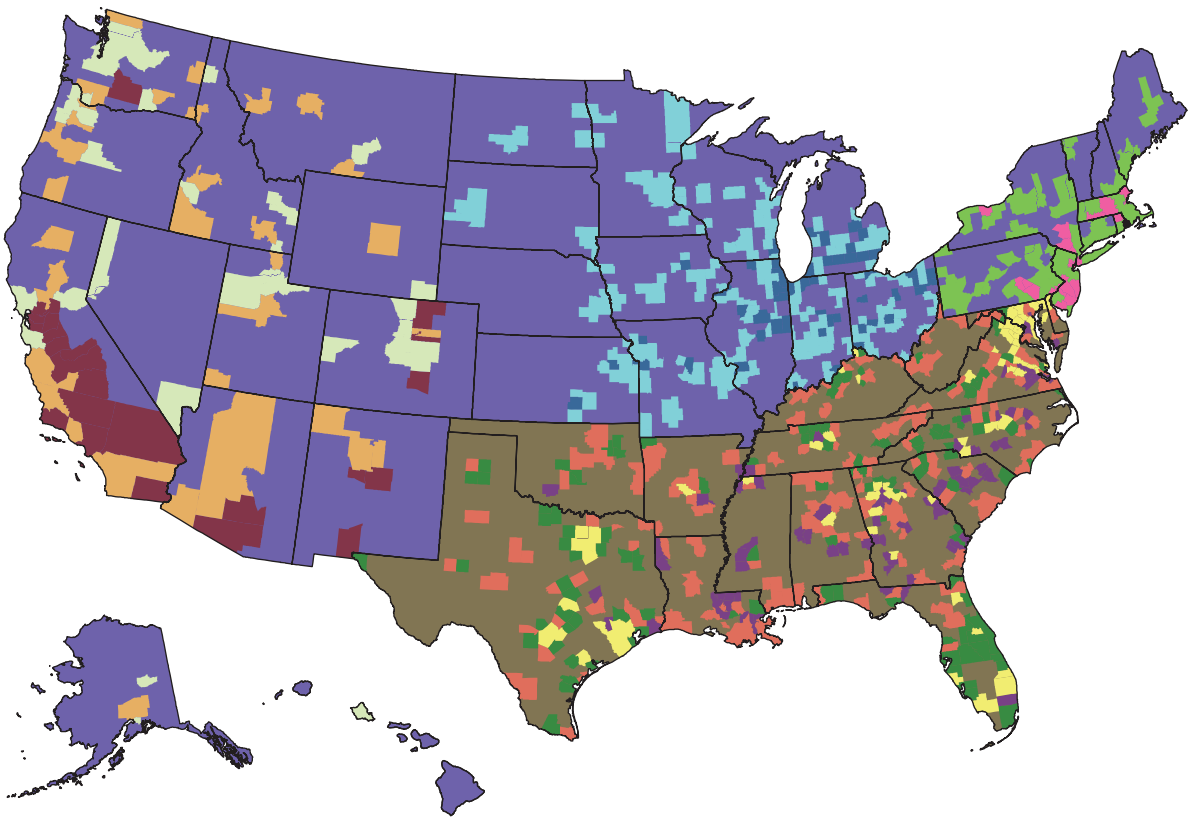
[2]Includes additional target of 150 examinations of low-income non-Hispanic white and other persons over age 1 year, altering their sampling rates and base weights. All other rates and base weights remained unchanged.

[3]Corresponds to a 150% sample; sampling rates may be calculated by dividing the numerator by 1,618.

Table III. Description of interview, examination, and laboratory subsamples: National Health and Nutrition Examination Survey, 2007–2010

Characteristic of interest, by sample collected	Ages (years) included	Sample fraction (of age group)	Random groups included[1]
Examination			
Blood pressure:			
OMRON device first, mercury second (2009–2010 only)	8 and over	1/2	1, 2, 5, 6, 9, 10
Mercury first, OMRON device second (2009–2010 only)	8 and over	1/2	0, 3, 4, 7, 8, 11
Taken by a health technician (2009–2010 only)	12 and over	1/2	0, 1, 4, 5, 6, 7
Blood			
Folates	1 and over	1/3	1, 2, 5, 11
Persistent pesticide residues and metabolites, dioxins, furans, PCBs, [PAH hemoglobin adducts, thyroid function (2009–2010 only)]	12 and over	1/3	1, 2, 5, 11
Organic fluorochemicals, nonpersistent pesticides	12 and over	1/3	4, 6, 8, 9
Brominated flame retardants	12 and over	1/3	0, 3, 7, 10
Tap water, blood			
Volatile organic compounds	12 and over	1/2	1, 2, 4, 5, 10, 11
Tap water			
Perchlorate	12 and over	1/2	1, 2, 4, 5, 10, 11
Urine-persistent organochlorine pesticides, nonpersistent pesticides including organophosphate pesticide residues [caffeine (2009–2010 only)]	6 and over	1/3	4, 6, 8, 9
Polyaromatic hydrocarbons, phthalates	6 and over	1/3	0, 3, 7, 10
Phytoestrogens	6 and over	1/3	0, 3, 7, 10 (2007–2008) 1, 2, 5, 11 (2009–2010)
Heavy metals, speciated arsenic, mercury, iodine [perchlorate (2009–2010 only)]	6 and over	1/3	1, 2, 5, 11
Washed cells			
Acrylamide (2009–2010 only)	6 and over	1/3	1, 2, 5, 11

[1]Each group is a random 1/12 sample.



Major stratum	Description
1	Nonmetropolitan Southern PSUs
2	Nonmetropolitan Northeastern, Western, and Midwestern PSUs
3	Metropolitan Northeastern PSUs with population less than 15.1% black and: – Less than 4.8% Hispanic; or, – More than 4.8% Hispanic and less than 5.8% white and other in poverty
4	Metropolitan Northeastern PSUs with population: – Less than 15.1% black, more than 4.8% Hispanic, and more than 5.8% white and other in poverty; or, – More than 15.1% black
5	Metropolitan Midwestern PSUs with population: – Less than 7% black; or, – More than 7% black, less than 7.6% Hispanic, and less than 6.4% white and other in poverty
6	Metropolitan Midwestern PSUs with population more than 7% black and: – Less than 7.6% Hispanic and more than 6.4% white and other in poverty; or, – More than 7.6% Hispanic
7	Metropolitan Southern PSUs with population less than 21.1% black and less than 6.6% white and other in poverty

Major stratum	Description
8	Metropolitan Southern PSUs with population less than 21.1% black and between 6.6% and 9.7% white and other in poverty
9	Metropolitan Southern PSUs with population: – Less than 21.1% black and more than 9.7% white and other in poverty; or, – Between 21.1% and 35.4% black and less than 5.5% Hispanic
10	Metropolitan Southern PSUs with population: – Between 21.1% and 35.4% black and more than 5.5% Hispanic; or, – More than 35.4% black
11	Metropolitan Western PSUs with population less than 9.3% black, less than 27.7% Hispanic, and less than 10% white and other in poverty
12	Metropolitan Western PSUs with population: – Less than 9.3% black, less than 27.7% Hispanic, and more than 10% white and other in poverty; or, – Less than 9.3% black, more than 27.7% Hispanic, and less than 8.5% white and other in poverty
13	Metropolitan Western PSUs with population: – Less than 9.3% black and more than 27.7% Hispanic, and more than 8.5% white and other in poverty; or, – More than 9.3% black

NOTES: PSU is primary sampling unit. For confidentiality purposes, PSUs selected with certainty are not identified and are placed instead into strata according to their demographics. Threshold values are approximate.
SOURCES: CDC/NCHS, National Health and Nutrition Examination Survey, 2007–2010; U.S. Census Bureau, 2000 and 2003 data for major strata, including such variables as census region (Northeast, Midwest, South, and West), metropolitan statistical area status, minority concentration, and percentage below poverty level.

Figure. Major strata formed for selection of 2007–2010 primary sampling units: National Health and Nutrition Examination Survey, 2007–2010

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