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Challenges in the Design of the National Health and Nutrition Examination Survey

Leyla Mohadjer[1], and Lester R. Curtin[2]

Abstract

The National Health and Nutrition Examination Surveys (NHANES) is one of a series of health-related programs sponsored by the United States National Center for Health Statistics. A unique feature of NHANES is the administration of a complete medical examination for each respondent in the sample. To standardize administration, these examinations are carried out in mobile examination centers (MECs). The examination includes physical measurements, tests such as eye and dental examinations, and the collection of blood and urine specimens for laboratory testing. NHANES is an ongoing annual health survey of the noninstitutionalized civilian population of the United States. The major analytic goals of NHANES include estimating the number and percentage of persons in the U.S. population and in designated subgroups with selected diseases and risk factors. The sample design for NHANES needs to create a balance between the requirements for efficient annual and multiyear samples and the flexibility that allows changes in key design parameters to make the survey more responsive to the needs of the research and health policy communities. This paper discusses the challenges involved in designing and implementing a sample selection process that satisfies the goals of NHANES.

KEY WORDS: Multi-stage Sampling, Domain Sampling, Weighted Measure of Size, Mobile Examination Centers.

1. Introduction

The National Health and Nutrition Examination Survey (NHANES) is one of a series of health-related programs sponsored by the United States Centers for Disease Control and Prevention (CDC) through it's National Center for Health Statistics (NCHS). The NHANES surveys have been designed to assess the health and nutritional status of the noninstitutionalized population in the United States for over 45 years. The data collected in NHANES are used to estimate the prevalence of major diseases and risk factors for diseases. The nutritional data from NHANES provides temporal monitoring of the nation with respect to such factors as diet, cholesterol, hypertension, iron deficiency, anemia, and obesity. NHANES has also been designed to assess the relationship between diet, health and the environment so that nutritional assessments can be linked to such diseases as cardiovascular disease, diabetes, hypertension, and osteoporosis.

Data collection for NHANES includes at least three stages: a household screener, an interview, and a medical examination. The primary objective of the screener is to determine whether any household members are eligible for the interview and examination. The screener collects basic information on household composition and demography. The interview collects household, family, and person-level data on demographic and socio economic background, health, and nutritional characteristics. Upon completion of the interview, respondents are asked to participate in a medical examination. To standardize administration and protocols, these examinations are carried out in a specially designed and equipped mobile examination center (MEC). The examination includes physical measurements, tests such as eye and dental examinations, physiological measurements, and the collection of blood and urine specimens for laboratory testing. The NHANES website http://www.cdc.gov/nchs/nhanes.htm provides detailed information about the NHANES medical components.

The development of an efficient design involves consideration of several design issues unique to NHANES in addition to the ones normally involved in survey samples. This paper is focused on the unique and challenging

[1] Leyla Mohadjer, Westat, 1650 Research Blvd., Rockville, Maryland, U.S.A. 20850, LeylaMohadjer@Westat.com

[2] Lester R. Curtin, National Center for Health Statistics, 3311 Toledo Road, Hyattsville, Maryland, U.S.A. 20782, lrc2@cdc.gov

aspects of the NHANES design. However, it is helpful to provide an overall summary of the NHANES design, as given below, before discussing the unique features.
The NHANES sample represents the total noninstitutionalized civilian population in the United States. Active military and institutionalized persons are not part of the population of inference. A four-stage sample design is being used. The Primary Sampling Units (PSUs), often referred to as stands, are selected from a frame of all U.S. counties. The PSUs are mostly single counties; in a few cases, adjacent counties are combined to keep PSUs above a certain minimum size. NHANES PSUs are selected with probabilities proportionate to a measure of size (PPS). There are 15 stands in each annual sample.

The second sampling stage is area segments comprising Census blocks or combinations of blocks. Within PSUs an average of 24 segments are sampled. The sample is designed to produce approximately equal sample sizes per PSU, and most PSUs have exactly 24 segments. The segments are also selected with PPS. The measures of size of the segments, when combined with the subsampling rates used within the segments, provide approximately equal numbers of sampled persons (SPs) per segment, although the relative variation in workload is greater among segments than among PSUs.

The third stage of sample selection consists of households and noninstitutional group quarters, such as dormitories. In a given PSU, following the selection of segments, all dwelling units (DUs) in the sampled segments are listed, and a subsample of households and group quarters within the DUs are designated for screening in order to identify potential SPs for interview and examination. SPs within the households or group quarters are the fourth stage of sample selection. All eligible members within a household are listed, and a subsample of individuals is selected. Each annual sample includes about 5,000 SPs with completed interviews and examinations.

The NHANES examination requires both highly specialized personnel and laboratory processing of collected specimens. As a result, examination components can be very costly to implement. In order to limit costs and reduce respondent burden, certain examination components are administered to only a subsample of MEC respondents. A single subsampling algorithm controls the amount of overlap among the various subsamples to allow analyses of correlations between various examinations and laboratory components. The SP's assignments to subsamples are fully determined prior to SPs arriving at the MEC.

The data collected in NHANES surveys have been extremely important in providing needed information about the health and nutritional status of the United States population. As a result, beginning with NHANES 1999, the survey has been implemented as a continuous, ongoing, annual survey (Montaquila et al (1998)). It is critical to devote a lot of attention to the development and maintenance of an efficient sample design for such a critical and complex survey. This paper discusses the challenges involved in designing and implementing a sample selection process that satisfies the multiple goals of NHANES. The paper focuses on the sample design used through 2006 (in response to the emerging analytical requirements, some aspects of the sample design will change starting in 2007).

Section 2 outlines the major purposes and goals of the survey, followed by an overview of the major factors affecting the design in Section 3. The unique features of the NHANES sample design is described in Section 4. Finally, Section 5 provides a brief summary of the paper.

2. Major Purposes and Goals of NHANES

NHANES is an ongoing annual health survey of the noninstitutionalized civilian population of the United States. The main objectives of NHANES are to: (1) estimate the national prevalence of selected diseases and risk factors; (2) estimate national population reference distributions of selected health parameters and environmental contaminants; (3) document and investigate reasons for secular trends in selected diseases and risk factors; (4) contribute to the understanding of diseases etiology; (5) investigate the natural history of selected diseases; (6) study the relationship between diet , nutrition, environment, genetics and health; and (7) explore emerging public health issues.

3. Major Factors Affecting Sample Design

As mentioned above, a unique feature of NHANES is the complete medical examination carried out in the MECs. In addition, the design needs to produce efficient sample sizes for a large number of subdomains of the general population. Many health and nutritional characteristics differ considerably by age, gender, and race/ethnicity, and are also impacted by the income status. As a result, most analyses of NHANES data are conducted for defined age categories within various socio economic subgroups of the population. Therefore, the survey is designed to produce efficient sample sizes for a very large number of subdomains of the U.S. population.

In general, the sample design for NHANES needs to create a balance between the requirements for efficient subdomain samples, and efficient workload for examination staff at the MEC, while keeping response rates as high as possible. More specifically, the NHANES design attempts to: (1) obtain prespecified self-weighting sample sizes for a set of about 75 predesignated subdomains; (2) produce sample size per PSU that comprise efficient workload for the interview and examination staff at the MEC; (3) design samples that are likely to achieve high response rates; (4) be as cost effective as possible; (5) produce efficient annual samples; (6) allow for accumulation of samples, especially for rare subdomains or rare diseases over time; and (7) be flexible to allow changes in key parameters, including sampling domains, and sampling rates to respond to emerging health issues.

In the remainder of this section, we provide brief summaries of how each of these goals impacts the design and implementation of NHANES.

NHANES Subdomains - The sample design for NHANES meets a prespecified level of precision for cross-sectional data and comparisons over time for a set of predesignated subdomains. Specifically, 77 sampling domains (in the 2006 sample) are defined by race/ethnicity, gender, age, income, and pregnancy status. The sample includes oversamples of blacks, Mexicans, the very young, adolescents, the elderly, pregnant women, and the low-income population.

When estimates of universe totals for the entire population are considered to be of the greatest importance, then the best available estimate of the total population is used as a measure of size in the sample selection process. For NHANES, where the interest is in subdomains of the total population, an alternative measure of size is needed to improve the accuracy of the estimates and provide better control of the sample size. Section 4 describes the measures of size used for sampling PSUs and segments in NHANES.

The objective of oversampling (using differential probabilities of selection) is to achieve a sample containing proportionately more members of certain population subdomains than there are in the population. The goal is to obtain adequate sample sizes to make inferences for subdomains representing relatively small proportion of the total universe of interest and to do it in such a way as to minimize variances for the budget available for the survey. Different oversampling strategies are used depending on the domains of interest. For example, oversampling of the minority subpopulations is accomplished through stratifying geographic areas by concentration of these minority groups, and selecting segments in high concentrated areas at a higher rate. On the other hand, a large screening sample may be required to oversample persons within specific age categories. The following subsection on Cost Ratios describes why oversampling procedures used in NHANES are different from many common area frame sample surveys.

Mobile Examination Centers (MECs) - The MEC consists of four specially designed and equipped trailers and contains all of the medical equipment. Each trailer is approximately 45 feet long and 10 feet wide. Detachable truck tractors drive the trailers from one location to another. MECs travel to survey locations throughout the country. The trailers are set up side-by-side and connected by enclosed passageways. The area in the MEC is divided into rooms to allow privacy during the exams and interviews. The examination includes a variety of physical and dental assessments and measurements, laboratory tests, and other health interviews.

Considering the logistical issues related to the traveling MECs, the sample size in each sampled location must be derived ahead of time and considered fixed so that field operations could be scheduled in an efficient and manageable way. Also, it is necessary to establish a firm time schedule for each stand so that appointments can be

made for examination. It is not possible to change the time schedule since it must be coordinated with the MEC's visit to other stands which are also planned in advance.

Response Rates- Achieving high response rates is a concern for practically every sample survey. With NHANES, this is a particular challenge because of the extensive nature of the interviews and examinations. Remunerations have been used in NHANES as a means of improving response rates. In addition, NHANES has an extensive outreach program including contacts with local organizations and individuals to gain cooperation, and local media coverage to reach as many SPs as possible. As a sample design issue, one approach that has proved to favorably affect response rates is selecting larger sample sizes within sampled households. One of the factors thought to be responsible for the increased response rates in multiple-SP households is that each person is given remuneration for his or her time and participation, and it is generally more convenient for household members to come to the MEC at the same time.

The NHANES is, therefore, designed to maximize the number of SPs per household. Such an approach is feasible for studies like NHANES where the sample is comprised of a large number of subdomains. That is, the effect of within-household clustering is not a large concern for NHANES because most analyses are done within age-gender specific subdomains (or some limited groups of subdomains) and there is generally little within-household clustering at the subdomain level.

Cost Ratios- The field data collection cost in area survey samples includes the cost of listing DUs, screening households to locate eligible respondents, and conducting the interview to collect data. In NHANES, the data collection phase includes both the household interview and the MEC examination. NHANES requires highly specialized medical equipment, personnel, and laboratory processing. As a result, the cost of an examination is very high compared to other costs in the survey. In fact, the cost of listing and screening is only about 3 to 4 percent of the cost of interviewing and examination. This cost ratio (the cost of interviewing and examination relative to the cost of listing and screening) greatly impacts the design of NHANES.

As mentioned above, many of the predesignated subdomains of NHANES require some method of oversampling to achieve the required sample sizes. For the minority populations, substantial reductions in screening are possible with oversampling of highly concentrated minority areas. In general, an optimum design is developed by ascertaining the effect on cost and variance of alternative sampling procedures and choosing the one that minimizes the variance for a fixed cost. In the evaluation of trade offs between cost and variance, suppose a particular oversampling strategy reduces the number of households to be listed and screened, while increasing the variance for most statistics. The savings brought about by the reduction in cost of listing and screening could be used to increase the size of the sample and thereby lowering the variance. However, in NHANES, listing and screening a household is only a very small fraction of cost, and thus, it takes very large savings in listing and screening costs to justify a moderate increase in variance. As a result, the oversampling procedures established for the survey reflect the NHANES cost ratio, and are different from typical area surveys.

Flexible Design- A critical objective of NHANES is to explore emerging public health issues. The survey needs to be flexible and able to adapt to changing requirements and new challenges. Thus, the sample design must balance the need for efficient subdomain samples with the flexibility needed to make changes in key parameters. To date the current NHANES design has been able to incorporate small changes in subdomain definitions and sampling rates when these changes have been made after the selection of PSUs. However, in extreme circumstances, substantial changes in subdomain definitions or sample size requirements would necessitate the selection of a new PSU sample.

Annual and Multiyear Samples- To facilitate potential linkage with other large-scale surveys, to retain flexibility in the sample design, and to allow for the production of annual estimates for broad subdomains, NHANES became a continuous, annual survey starting in 1999. The travel requirements for nationally representative annual samples in the U.S. are challenging. Three MECs—two of which are stationed at PSUs and one of which is traveling at any given time—work with a very carefully designed schedule to meet the design requirements of the study.

The ability to make meaningful inferences from any survey is affected by both the precision of the estimates themselves and the precision of the variances of the estimates used in the analysis. One of the main limitations of an NHANES annual sample is the small number of PSUs (15 per year), which results in a small number of degrees of freedom for both estimation and analysis and thus, design-based variance estimates that are relatively imprecise.

Additionally, the effective sample sizes for most subdomains are too small in annual samples. Most subdomain analyses will need to accumulate a number of annual samples for both precision and statistical power for comparisons. The procedures for combining years of the survey must be relatively simple, and appropriate for commercial software packages, to maximize the usefulness to the wide variety of users of the NHANES data. Thus, it is critical to employ a sample design that allows efficient accumulation of the annual samples across years.

4. Unique Features of the NHANES Design

The factors described in Section 3 play major roles in the development of the sample design, and result in some design features that are unique to NHANES. The unique features of the sample design includes: (1) weighted PSU and segment measure of size (MOS); (2) a very large screening sample; (3) efficient annual and multiyear samples; (4) maximized number of SPs per household; (5) controlled sample sizes for PSUs; (6) sequential release of the PSU sample; (7) special methods to deal with deterioration of the efficiency of the optimum design over time; and (8) special methods to reduce the risk of data disclosure through geographic identification.

The following provides brief descriptions of the unique features of the NHANES design.

Measures of Size (MOS) - In NHANES, the sample size must be large enough to produce an efficient workload for each PSU, considering the time and the cost involved in moving a MEC between survey locations and the time required to set up and break down the MECs for travel. Research has shown that an average of about 340 examined SPs is an approximately optimum number that provides the maximum number of PSUs, while keeping the sample size in each area large enough to justify the costs associated with moving the MECs. In addition, the PSUs for NHANES are typically defined as individual counties to reduce the amount of travel necessary for respondents to visit a MEC, and thereby increase the likelihood of achieving high response rates.

The NHANES sample is designed to yield a self-weighting sample for each sampling subdomain, while producing an efficient workload in each PSU. PSUs and segments are selected with probabilities proportionate to a weighted MOS, reflecting the PSU population in subdomains of interest. The selection probability of a PSU determines the maximum rate at which persons residing in that particular PSU can be selected. Refer to the *Vital and Health Statistics, Series 2, No. 113, September 1992, CDC/NCHS*, available at http://www.cdc.gov/nchs/products/pubs/pubd/series/sr02/120-101/120-101.htm for a description of the measures of size used in NHANES.

Annual and Multiyear Samples- One way to achieve nationally representative annual samples is to select an independent sample of PSUs each year. For NHANES, due to the limited number of PSUs and the fact that PSUs are selected proportionate to size, this approach would be likely to lead to substantial overlap in PSUs from year to year. Sample overlap, even at the PSU level, could lead to loss of precision of survey estimates when survey years are combined (due to increased clustering of the sample). Thus, rather than sampling PSUs independently each year, the approach in NHANES has been to select a 6-year sample, from a nested structure of major and minor strata (as described below), and then allocate one PSU from each major stratum to each year. This nested structure for the 6-year sample avoids overlap of non-self-representing PSUs during the 6 years.

The stratification scheme for the NHANES 6-year sample is developed with the primary goal of efficiency for the 6-year sample as well as efficient multiyear samples. The stratification scheme is designed to ensure that the PSUs comprising the annual and multiyear samples are distributed evenly in terms of geography and certain population characteristics.

For the current NHANES, twelve major strata were defined based on geography and the Metropolitan Statistical Area (MSA) status of the PSUs. Seventy-two minor strata were defined based on the demographics of the PSUs. Each major stratum included six minor strata, and one PSU was selected from each of these final strata. Within each major stratum, minor strata were paired. Each pair was randomly assigned to the study years 3 years apart. The assignment of the pairs to the particular sets of study years and the assignment of the study years within the pair were random within the first major stratum, and all other major strata followed the same pattern.

This stratification scheme produces efficient annual and multiyear estimates without compromising the efficiency of the 6-year estimates. The 6-year sample has a one-PSU-per-minor stratum design; and each annual sample has a one-PSU-per-major-stratum design

The minor strata were constructed to be of equal size to the extent possible (in terms of total MOS). A randomized procedure is used to assign PSUs to annual samples. The self-representing PSUs are sorted according to MOS and the non-self-representing PSUs are sorted by order of selection. The PSUs are then paired off, and the year is assigned using a randomly determined pattern. Within each pair, the PSUs are assigned three years apart.

Maximized Number of SPs Per Households- After the sample of screened households is identified, a sample of persons to be interviewed and examined from individual households is selected. All eligible members within a household are listed and a subsample of individuals is selected based on gender, age, race/ethnicity, and income (all pregnant women are selected with certainty). Sample persons are selected at rates established to ensure that the target sample sizes by subdomains will be achieved.

The sample of SPs is selected in a way that maximizes the average number of sample persons per household in order to increase the overall response rate in the survey. If independent random selections are made for the subdomains, in most cases, only one person in a household would be selected and the average sample size per household would be quite low, not much above 1. Therefore, instead of unrestricted randomization, a pseudo-random procedure is used that maximizes the number of SPs per households. Refer to Waksberg, Mohadjer (1991) for a description of the approach.

Controlled Sample Sizes Per PSU- The sample size in each PSU (stand) that is actually generated from a self-weighting sample in each domain is based on a number of assumptions such as the age and race/ethnicity distribution in the PSU. These assumptions hold only approximately. Once the sample sizes have been calculated, they are treated as quotas, and the number of SPs in each stand is forced to adhere closely to the quota. The reason for this procedure is to have a manageable and efficient field operation. It is necessary to establish a firm, and fixed time schedule for each stand so that appointments can be made for SP examinations. The time schedule obviously takes into account the expected number of SPs in each stand. As mentioned earlier, it is difficult to change the time schedule for a stand since it must be coordinated with the MEC's visits to other stands which are also planned in advance.

There is no way of knowing in advance whether the assigned quota for a particular stand is lower or higher than what would arise from self-weighting samples within the various domains. Part of the reason for the uncertainty is that the MOS used for sample selection is based on the latest decennial Census and may not be quite up to date. The issue is further complicated by variations in response rates from stand to stand as well as sampling variation in the number of identified SPs. Consequently, it is necessary to use a sample selection procedure that can produce samples that are either somewhat larger or somewhat smaller than those arising from the application of the self-weighting sampling rates.

Sequential Release of the Sample in Each Stand- To accomplish the above objective, an initial sample is selected in each stand that uses sampling rates 50 percent larger than those required to attain the target sample sizes in each domain. Each stand's initial sample is then divided into a group of subsamples. Each subsample is a systematic subsample of the initial sample, with the households sequenced by segment number and a temporary, geographically based sequence number prior to subsampling. Thus, each subsample cuts across all segments, except when limited by sample size.

As a general rule, the 50 percent subsample (i.e., subsample A) is released to the interviewers first. The yield from this subsample is monitored and used to project estimates of the total number of SPs expected when screening of this subsample has been completed. Based on these figures, additional subsamples are released as needed. The sample is monitored on a daily basis to determine whether additional subsample releases are required.

The one operational problem with the procedure to monitor the sample yield is that it cannot completely control the subdomain sample sizes. The distribution of subdomains differs, to some extent from the expected numbers based on the most recent Census data (used to derive the sampling rates). Experience with NHANES indicates that some changes in the population that affect the sample sizes can be expected. Other factors that impact subdomain sample

yield are patterns of nonresponse and undercoverage in stands. One option to correct the shortfall (or overage) in subdomain sample sizes is to change the sampling rates in future stands. However, such changes will increase heterogeneity in sample weights, thus adversely affect the precision of the subdomain estimates and are not advisable except under extreme circumstances.

Dealing with Deterioration of the Efficiency of the Optimum Design over Time in a Tightly Controlled Sample- The usual practice in area samples is to list all households in the sample segments and apply a prespecified sampling rate to the listed households. This approach gives all households the desired probabilities of selection. For example, if the sampling rate is 50 percent, then one-half of the housing units listed in the segments will be included in the sample. If the number of housing units 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.

For NHANES, highly variable sample sizes are not feasible because of the scheduling requirements of the MECs. Subsampling within PSUs, in an effort to attain equal sample sizes across PSUs, is not recommended either because it will introduce unequal weighting factors that would reduce the efficiency of the sample.

NHANES has used two procedures to update the segment MOS, 1) creation of new construction segments, and 2) two-phase sampling to update the MOS. Currently, a third approach is under consideration, in which purchased commercial address listings are used to update the MOS in a two-phase sampling design.

Under the new construction approach (Bell et al (1999)), newly constructed units are excluded from area segments and new segments are created based on information available from Census on permits issued for new construction since the most recent Decennial Census. New construction segments comprise clusters of building permits issued during one or several adjoining months by a building permit office. Census Bureau files from the Building Permits Survey are used as sources of the data on the number of residential building permits issued by the building permit offices.

Two-phase sampling is used in a number of statistical applications. One of the applications of two-phase sampling is 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. With this approach a larger sample of units (in the case of NHANES, the units are segments) is selected. An updated value of MOS is then collected for this larger sample (also referred to as the first-phase sample). The final sample of units (segments) is selected from the first-phase sample using the updated MOS.

Starting in 2000, the NHANES segment MOS has been updated (for stands for which such updating seemed necessary) using a two-phase sampling procedure (Montaquila et al (1999)). In these cases, listers travel to the stand to obtain a count of the number of dwelling units (DUs) in each segment in the first-phase sample. Using the listers counts, an updated MOS that reflects the ratio of the actual number of DUs to the expected number of DUs is calculated for each first-phase segment. The final sample of segments is then selected by subsampling from the first-phase segments using the updated MOS.

Risk of Data Disclosure Through Geographic Identification- In today's world, confidentiality concerns and the risk of data disclosure present real challenges to survey sponsors. The ability to identify survey respondents, either through unique combinations available on a single data file or by linking different databases is of great concern. This is particularly true for NHANES, due to the extensive amount of sensitive data collected on each SP, and the small number of PSUs in the sample. Therefore, NHANES evaluates the risk of disclosure on two fronts: geographic disclosure, and disclosure from individual characteristics. Various methods (limited or suppressed data release) are used by NCHS to mask the individual characteristics that have a high risk of identifying individuals in the NHANES sample. Sensitive, limited, or non-released data items are available through a Research Data Center (RDC). At this time, only national estimates can be produced from publicly available data files, detailed geographic analyses must be done in the RDC.

Although only national estimates can be produced, the direct estimation of sampling errors for those national estimates requires the release of design variables such as stratum and PSU identifiers. Typically, these variables indicate that a group of SPs are all in the same county but does not identify that county. Geographic disclosure is of

a particular concern because the NHANES; (1) has a small number of PSUs, (2) PSUs are limited in geography to one county, and (3) because an extensive amount of outreach activities are conducted within each PSU to improve response rates. The outreach program includes contacting various organizations and individuals at each stand to seek their support, and using media (newspapers, television, and radio) to reach as many SPs as possible. It is, therefore, relatively easy to determine the counties and data years where the NHANES stands have been. The race/ethnic composition of a county along with metropolitan/non-metropolitan status is enough information to correctly match a list of known counties with groups identified as a county cluster on the public data file. To limit geographic disclosure, probabilistic record swapping methods are used at the second stage of sampling (segment swapping) to create masked variance units. The goal is to reduce the risk of identifying individuals by masking their location. Refer to Park et al (2006) for a description of the swapping procedures applied to the NHANES sample.

5. Summary and Conclusions

A unique feature of NHANES is the complete medical examination carried out in the MECs. In addition, the survey is designed to produce efficient sample sizes for a large number of subdomains of the U.S. population since most analyses of NHANES data are conducted for defined age categories within various socio economic subgroups of the population. Thus, the sample design for NHANES needs to create a balance between the requirements for efficient subdomain samples, and efficient workload for examination staff at the MEC, while keeping response rates as high as possible. In addition, the design needs to be as cost effective as possible, produce efficient annual samples and allow for accumulation of samples for rare subdomains or rare diseases over time. Furthermore, the design needs to be flexible to allow changes in key parameters, including sampling domains, and sampling rates to respond to emerging health issues.

The above requirements result in a very complex design with some design features that are unique to NHANES. In particular, the current sample is designed to produce efficient annual and multiyear samples. NHANES uses weighted PSU and segment measure of size (MOS) to yield self-weighting samples for each subdomain, while producing an efficient workload in each PSU. Once the sample sizes are calculated, they are treated as quotas. The sample sizes are strictly controlled in each PSU to create a manageable and efficient field operation. A very large screening sample is used to oversample most of the age and income subdomains, and oversampling of highly concentrated areas is used for some of the very rare minority subdomains. The sample of SPs is selected using a pseudo-random procedure to maximize the average number of sample persons per household because it appeared to increase the overall response rate in previous surveys.

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