NONRESPONSE ADJUSTMENTS IN A NATIONAL HEALTH SURVEY

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Introduction

The National Health and Nutrition Examination survey (NHANES) is a periodic national survey conducted by the National Center for Health Statistics (NCHS). The NHANES is designed to provide national statistics on the health and nutritional status of the civilian noninstitutionalized population through household interviews and standardized physical examinations. The physical measurements and physiological tests are conducted in specially equipped mobile examination centers (MEC's) that are transported to each survey location. The on-going Third National Health and Nutrition Examination Survey (NHANES III) is the seventh in a series of surveys using health examination procedures that have been conducted since 1960 by NCHS. The target population for the survey is the civilian noninstitutionalized population aged 2 months and older. The NHANES III with a sample of approximately 40,000 persons has been divided into two 3-year surveys (phase 1 and phase 2) so that national estimates can be produced for each 3-year period as well as for the total 6 years.

The NHANES III survey is based on a complex, multistage area probability sample design. Children under 5 years of age, older Americans aged 60 years and older, Mexican Americans, and Black Americans are sampled at a higher rate than other persons. Details of the sample design of NHANES III have been previously published (1).

The NHANES, like most sample surveys experiences unit or total nonresponse despite special procedures designed to maximize response rates. These procedures include extensive publicity in each survey location, a home examination especially targeted for the older population, a remuneration to all survey participants, and a report of major medical findings. Since NHANES includes both an interview and an examination component, two levels of unit nonresponse occur. That is, some persons randomly selected for the survey refuse to be interviewed and/or examined. NHANES III-phase 1 conducted from 1988-91 included 20,277 sample persons. In-person household interviews were conducted with 17,464 persons (86%) and physical examinations were conducted with 15,884 persons (78%). For 12,391 adults 17 years and older, the interview and examination rates were slightly lower at 82% and 73%, respectively.

Since NHANES III is based on a complex stratified multistage design, the responses of each respondent must be inflated or weighted in order to produce national estimates of diseases and health and nutritional characteristics for the U.S. population and selected subgroups. As for the previous NHANES, the construction of sample person weights for statistical analysis and public use data tapes consists of the basic sampling weight (the reciprocal of the probabilities of selection); a nonresponse adjustment factor; and a poststratification factor by age-sex-race/ethnicity groups based on known population cell counts. The final weight for each sample respondent is the product of these three weighting factors. This paper describes the process of selecting variables related to nonresponse and the procedure for adjusting the sampling weights for interview and examination nonresponse in order to reduce potential bias in the estimates from NHANES III.

Methods

Adjustment for unit nonresponse is usually made by grouping respondents and nonrespondents into a relatively small number of homogeneous classes (adjustment cells) and weighting respondents in each class up to the level of the full sample (2,3). Weighting class adjustment for unit nonresponse has been used in previous NHANES surveys and the same general procedure is being used for NHANES III. The analyses in this paper focus on adults 17 years and over. Alternative weighting adjustments for examination nonresponse were evaluated where examination status was defined as sample persons examined in the MEC. For this analysis persons examined in the home were treated as nonexamined. An abbreviated home examination was offered to those persons unwilling or unable to travel to the mobile examination center (MEC) for the full examination. A separate weight will be developed in the future for analysis of those survey components common to both the MEC and the home examination. Additional weights will also be calculated for components done on a subsample.

Potential adjustment class variables

Weighting class adjustment requires that the classifying variables used to construct the classes be available for all units in the sample (4). In constructing analysis weights for prior NHANES surveys, variables such as age, sex, race, family income, household size, region, and urbanization status were used to classify respondents and nonrespondents into adjustment classes for both interview and examination nonresponse. Use of these variables, or a subset, is still required when adjusting for interview nonresponse since the only information available for noninterviewed persons is the demographic information obtained from the initial household screening questionnaire along with the region and urbanization status of each sample location. However, in selecting weighting class variables for adjustment of examination nonresponse, all of the household interview information is available for both examined and non-examined persons; thus a large set of potential health variables is available for evaluation of the adjustment for examination nonresponse. As a result, research on adjustments for examination nonresponse in NHANES III-phase 1 has focused on use of health history data in addition to demographic information to adjust the sampling weights for potential nonresponse bias. The screening response for NHANES III is virtually 100%, therefore no adjustment for screening nonresponse is needed.

Most surveys do not have data other than the standard demographic variables for use in forming weighting classes, but this is possible in NHANES since there are two levels of survey participation--interview and examination. It is reasonable to assume that the quality of the survey data may be improved if weighting classes for examination nonresponse are defined according to some definition of health cross-classified by selected demographic variables. However, if a

health variable is included in the adjustment, then there should be evidence that there is no excessive increase in the variance estimates. Only a few other surveys have attempted to use more substantive variables other than socio-demographic ones to adjust for nonresponse (5).

In the selection of variables, we have attempted to follow the guidelines suggested by Cox and others to keep the minimum cell size (weighting class) at about 20-25 to avoid excessive variance inflation, and to form classes for which the response rates vary and for which the means of survey outcome variables differ between classes (4, 6). This approach to adjusting sampling weights for nonresponse has been used by other large-scale government-sponsored surveys.

Based on a preliminary evaluation of potential weighting classes for NHANES III with the inclusion of a health variable to adjust for examination nonresponse, we concluded that using a one-stage adjustment procedure to weight up the examination respondents to all sample persons resulted in reduced sample size for the weighting classes (7). This was due to the large amount of missing health data primarily for non-interviewed persons. Therefore, our second phase of research has focused on the use of a two-stage adjustment procedure. The first adjustment is for persons screened but not interviewed for whom only age, sex, race/ethnicity, household size, and geographic location data are known. The second adjusts for persons who were interviewed but not examined. At this second stage, we have evaluated the use of a health variable in addition to socio-demographic information to adjust for examination nonresponse. Since more detailed health information is available for adults and an association between examination response and health is more likely to exist for adults, especially older adults, this paper focuses on the adult population 17 years and older. Since we do not think an adjustment for health is a relevant issue for children and youth, it will be deleted. Only demographic, geographic location, household size, and income information at stage II will be used for the examination nonresponse adjustment for children.

First-stage adjustment:

Adjustment for nonrespondents who did not complete the household questionnaire (interview)

Only screener information, age, sex, race/ethnicity, household size, and geographical information such as region and urbanization status are available for interview nonrespondents. Table 1 shows interview response rates for adults by selected characteristics. Age, race/ethnicity, region, metropolitan status, and household size are strong predictors of interview response. We also considered the use of family income to adjust for interview nonresponse but since this variable comes from the family questionnaire at the time of the household interview, income is missing for all non-interviewed persons and would have to be imputed for non-interviewed persons. Therefore, we decided to use income in the adjustment for examination nonresponse since income is fairly complete for all interviewed persons (13% item nonresponse). Gender was not strongly associated with interview nonresponse. Any adjustment for nonresponse or noncoverage by gender will be taken care of at the poststratification stage which is based on age, sex, race/ethnicity estimates from the U.S. Bureau of the Census for use as population control counts. As a result, 72 interview adjustment cells were formed for adults defined by the variables:

Age (2)	17-59 and 60+ years
Race/ethnicity (3)	White/other, Black, Mexican-American
Region (3)	North/central, south/southeast, west/southwest
SMSA (2)	Non-SMSA, SMSA
Household size (2)	1-4, 5+ persons

Second-stage adjustment:

Adjustment for nonrespondents who completed the household questionnaire but were not examined

We evaluated a broad spectrum of variables to adjust for examination nonresponse. We considered not only basic socio-demographic variables, region, metropolitan status, family income, and education, but also a wide range of self-reported health conditions from the household interview which might also be strong predictors of examination response. In addition to looking at examination response rates (tables 1 and 2) for selection of adjustment variables, we calculated unweighted rates of various health conditions for both examination respondents and nonrespondents. Those conditions with differences greater than three percent and with a sample size of 20 or more were flagged as potential weighting class variables.

In the next stage of exploratory analysis, a clustering technique was used to identify a potential set of classifying variables and to determine which subclasses of the variables should be used. The SI-CHAID (Statistical Innovation's Chi-Square Automatic Interaction Detection) software (8,9) was used to examine the relationship between examination response and various independent predictor variables. In brief, this method forms adjustment classes in such a way so as to maximize the variation in response rates. The result has a tree-like structure that suggests which predictor variables based on chi-square values may be most related to the dependent variable. For the SI-CHAID examination response model, we included several demographic, socio-economic, and medical history variables from the household interview. A list of variables similar to those in our preliminary analysis showed an association with response (7).

Odds ratios of examination response from logistic regression were also used to examine the relationship between selected independent variables and examination status. Unadjusted and adjusted odds of examination response for selected variables are shown in table 3. This table shows that all of the variables were significantly associated with examination response except for gender and the middle income group. However, after adjusting for age, sex, and race/ethnicity, most of the significant associations disappeared. Only HHSize, SMSA, back pain, chest pain, activity status, and poor/fair health status remained significant. Since we were interested in a general health related variable with low item nonresponse for possible inclusion in the weighting adjustment, we decided to evaluate the inclusion of self-perceived health status (dichotomized into excellent/very good/good and poor/fair) in the adjustment for examination nonresponse.

Using the above methods and variable selection criteria, we compared two examination nonresponse adjustment models at the second stage. Adjustment for examination nonresponse for youth and children uses only weighting model #1 as defined below:

Model #1: Age (2), race (3), household size (2), income (3)

Model #2: Age (2), race (3), household size (2), income (3), self-reported health status (2) (excellent/very good/good versus poor/fair)

Three levels of income were defined: $15,000 or less, $15,001-29,999, and $30,000+. However, income was collapsed for the 60+ years age group, because some of the cell sizes were less than 20. Also, missing family income was imputed for the interviewed sample for the purposes of weighting only; categories for the other variables were defined the same as for the interview nonresponse adjustment. Since most of the primary sampling units (PSU's) belong to the SMSA group and the initial basic weights are adjusted for region and urbanization (SMSA status) at stage I, we decided for the stage II adjustment to drop these two variables and include household size so as to keep the total number of adjustment cells small.

The nonresponse adjusted weights were then ratio adjusted to independent control estimates by age, race/ethnicity, and sex based on 1990 Current Population Survey estimates from the U. S. Bureau of the Census. Also before poststratification, the weights were trimmed within 8 age and 3 race/ethnicity groups to the 98th percentile. The trimmed or reduced weights were redistributed to form a new nonresponse adjusted truncated weight so as to maintain the total weighted counts.

Results

All of the interview and examination nonresponse adjustment factors were less than 2.0. The interview nonresponse adjustment factors ranged from 1.02 to 1.37, while the examination factors ranged from 1.00 to 1.42. The final adjustment factor for the MEC examination weights after post-stratification ranged from 0.4 to 2.6. Table 4 shows the distribution of the final nonresponse adjusted-truncated-poststratified MEC examination weights by race/ethnicity for models 1 and 2 (model 2 includes health status). The ratio of the 95th percentile to the median, the relative standard errors(CVs) and other statistics within each race/ethnicity group reveal no significant difference between the two models. However, all of these statistics differ by the three race/ethnicity groups. To compare the effect of the weighting models on the selected survey measures, the percent relative difference between the adjusted and unadjusted (using only the basic sampling weights) means were calculated (Table 5). Again, no significant difference was observed between the two models. The adjusted and unadjusted estimates differ slightly. We further looked for any variation in the design effects between the 2 models. No significant differences were noted, however, as might be expected the survey design effects differ across the three race/ethnicity groups for selected measurements (Table 6). Preliminary evaluation of the design effects for selected variables indicate that some sort of variance smoothing approach such as the average-design-effect may be needed for analysis of the NHANES III data (10).

Summary

In previous NHANES surveys nonresponse adjustments for both interview and examination response were made using only demographic characteristics and a few other data items such as income, household size, region and urbanization status. A more formal investigation of determinants of nonresponse was conducted for NHANES III, phase 1. Due to unit nonresponse to the interview portion of the survey and item nonresponse during the interview, a two stage nonresponse adjustment procedure is preferred over a one stage adjustment procedure for the examination component of NHANES III. A number of potential health variables were examined for inclusion in the 2-stage adjustment procedure for examination nonresponse in an attempt to reduce nonresponse bias. The potential variables were collected for both the examined and nonexamined population. Our research did not reveal any significant differences in the means or design effects for selected survey measures when statistical weights from two models were evaluated. We conclude that the inclusion of self-perceived health status in the adjustment for examination response should have a beneficial effect on reducing potential bias, especially in the older population, without increasing the variances excessively. Another benefit of using a two-stage weighting methodology for NHANES is that interview weights are a by-product of the adjustment for examination nonresponse. Therefore, no special computational step is needed for the interview weights.

References

1. Ezzati T, Massey J, Waksberg J, Chu A, Maurer K. Sample Design: Third National Health and Nutrition Examination Survey. National Center for Health Statistics. Vital Health Statistics. Series 2, No. 113, 1992.
2. Madow WG, Olkin I and Rubin DB, eds. Incomplete Data in Sample Surveys, Volume 1, Academic Press, New York, 1983.
3. Little RJA. Survey Nonresponse Adjustments for Estimates of Means. International Statistical Review 1986: 54:139-157.
4. Cox B. Weighting Survey Data for Analysis. Presentation for the ASA Continuing Education Program. 1991 Joint Statistical Meetings, August, 1991.
5. Goksel H, Judkins D, and Mosher W. Nonresponse Adjustments for a Telephone Follow-up to a National In-Person Survey. 1991 Proceedings of the Section on Survey Research Methods, 581-586, 1992.
6. Chapman DW. A Survey of Non-Response Imputation Procedures. Proceedings of the Social Statistics Section of the American Statistical Association. 245-251, 1976
7. Ezzati T and Khare M. Consideration of Health Variables to Adjust Sampling Weights for Nonresponse in a National Health Survey. 1991 Proceedings of the Social Statistics Section, 203-208, 1992.
8. Kass GV. An Exploratory Technique for Investigating Large Quantities of Categorical Data. Appl Statist 2:119-127, 1980.
9. Lee et al. Analyzing Complex Survey Data. Sage Publications, Newbury Park, CA., 1989.
10. Rowland M. NHANES III Design Effects and Weights. Unpublished memorandum. September, 1992.

Table 1. Interview Response Rates for Adults 17+ Years by Selected Variables NHANES III: Phase 1, 1988-91

	Interview Response Rates (%)[1]	Number of Interviewed Persons	Mobile Examination Center (MEC) Examination Rates for Interviewed Persons (%)[2]
Total	82	10,120	87
Age			
17-59	83	6,652	92
60+	79	3,468	78
Gender			
Male	81	5,048	87
Female	83	5,072	87
Race/Ethnicity			
White/Other	79	4,855	83
Black	85	2,554	91
Mexican American	83	2,711	90
Region			
South/Southeast	83	2,644	88
West/Southwest	82	4,040	88
Other	80	3,436	85
SMSA Status			
Non-SMSA	86	2,533	89
Non-certainty	81	5,246	86
Certainty	78	2,341	87
HHSize			
1-4	80	7,657	85
5+	88	2,463	93
Family Income (imputed)			
< 15,000	90	3,402	86
15,000-29,000	77	3,396	87
30,000+	79	3,322	88
Marital Status			
Currently Married		5,790	89
Formerly Married		2,242	81
Never Married		2,024	90
Missing		64	39
Education			
Elementary		2,233	84
High School		4,842	88
College		2,653	88
Never		257	91
Missing		35	59

[1]Denominator = all sampled persons
[2]Denominator = all interviewed persons

Table 2. Examination Response Rates for Adults 17+ Years by Selected Significant Health Characteristics* NHANES III: Phase 1, 1988-91

Characteristic	Examination Response Rates (%)[1]	Number of Examined Persons[2]
Total	87	8,805
Self-Perceived Health Status		
Excellent, Very Good, Good	88	6,640
Fair, Poor	84	2,165
High Blood Pressure		
Yes	84	3,192
No	89	5,609
Current Smoker		
Yes	89	2,524
No	86	6,281
Diabetes		
Yes	84	672
No	87	8,113
Chest Pain		
Yes	90	2,573
No	86	6,231
Back Pain		
Yes	89	2,059
No	86	6,144
Activity Status		
Same or More	88	6,703
Less	85	1,882

* Significant at 0.05 level.
[1] Denominator = all interviewd persons
[2] Excluding missing data.

Table 3. Odds Ratio of Examination Response by Selected Variables NHANES III: Phase 1, 1988-91

Variable Name	MEC only Odds Ratio (Examined)*	Adjusted Odds**
Age(60+)	0.33	
Race(B)	2.14	
Race(MA)	1.84	
HHSize(5+)	2.27	
Income(15-30K)	1.08	
Income(30K+)	1.25	
Gender(F)	0.95	0.96
SMSA(Y)	0.82	0.63
Region(W)	1.23	1.07
Region(S)	1.20	1.16
Health(P/F)	0.70	0.82
Smoking	1.28	1.02
Back pain	1.30	1.50
Chest pain	1.37	1.52
Diabetes	0.73	0.98
High BP	0.60	0.93
Activity Status	0.78	0.74
Education(HS)	1.34	1.07
Education(CL)	1.27	1.04
Currently married(Yes)	0.88	1.35
Formerly married(Yes)	0.46	0.89

* All Significant at 0.05 level, except for gender(F) & Currently married(Yes)
** Adjusted for Age, Race, HHsize, & Income

Table 4. Distribution of Final Examination Weights by Weighting Class Models for examinees only NHANES III: Phase 1, 1988-91

Weights	Race/ Ethn.	N	Mean	Median	Maximum	CV	5th	95th	95th/ median
Basic weights	White*	4032	23997.8	23561.9	111600	55.93	3381.8	45036.3	1.91
	Black	2332	6372.5	5819.8	48522	47.98	2625.3	12441.5	2.14
	Mex-Am	2441	2845.5	2831.0	13950	50.43	599.6	4650.0	1.64
Interview weights, Adj for Age,	White*	4032	33920.8	34229.0	101643	54.25	4753.0	62742.0	1.83
Race, HHsize, region, SMSA	Black	2332	8284.3	7756.0	224655	39.05	4195.0	15430.0	1.99
	Mex-Am	2441	3134.6	3304.0	6653	39.88	761.0	4913.0	1.49
Examination weight model #1	White*	4032	38814.1	38641.3	95173	50.14	7111.0	71007.2	1.84
	Black	2332	9019.9	8272.7	24962	37.36	4971.4	16203.7	1.96
	Mex-Am	2441	3433.7	3554.0	8299	40.33	890.0	5526.4	1.56
Examination weight model #2	White*	4032	38813.3	38619.2	95044	50.16	7244.1	70720.1	1.83
	Black	2332	9109.9	8262.7	24777	37.42	5005.5	16220.0	1.96
	Mex-Am	2441	3433.7	3551.6	8239	40.48	887.7	5546.8	1.56

*Includes White and others
Model #1: Age, race, household size, income
Model #2: Age, race, household size, income, self-reported health status

Table 5. Percent Relative Difference Between Adjusted and Unadjusted Means for Selected Examination Measurements NHANES III: Phase 1, 1988-91

MEC Examination Measurements WHITE/OTHER	N	Un-adjusted Mean	Adjusted Mean Model#1	Adjusted Mean Model#2	Rel.Diff= (Adj mean-Unadj mean) x 100/Uadj mean	
					Model#1	Model#2
Height(cm)	3932	168.46	168.63	168.63	0.10	0.10
Weight(Kg)	3831	73.97	74.24	74.26	0.37	0.39
BMI(Kg/m**2)	3818	25.98	26.02	26.02	0.15	0.15
Total Cholesterol	3792	203.12	204.78	204.78	0.82	0.82
HDL	3742	50.86	50.76	50.75	-0.20	-0.22
Glucose	3708	93.13	93.71	93.76	0.62	0.68
Hemoglobin	3758	14.11	14.14	14.14	0.21	0.21
Systolic BP	3875	119.55	120.39	120.41	0.70	0.72
Diastolic BP	3869	72.24	72.49	72.50	0.35	0.36

Model #1: Age, race, household size, income
Model #2: Age, race, household size, income, and self-reported health status

Table 6. Average Design Effects for Weighted Examination Measurements (Model #2) NHANES III: Phase 1, 1988-91

MEC Examination Measurements	Average Design Effect Over Age Groups								
	White/Other			Black			Mex-Am		
	All	Male	Female	All	Male	Female	All	Male	Female
Height(cm)	1.3	1.2	1.3	1.0	1.2	1.3	1.3	1.6	1.1
Weight(Kg)	1.1	1.3	1.0	1.5	1.3	1.4	1.2	1.2	1.2
BMI(Kg/m**2)	1.2	1.4	1.1	1.4	1.3	1.4	1.2	1.0	1.5
Total Cholesterol	1.1	1.0	1.0	1.5	1.4	1.3	1.7	1.8	1.1
HDL	1.3	1.0	1.2	1.5	1.2	1.5	2.4	2.4	1.3
Hemoglobin	1.3	1.6	1.1	1.4	1.0	1.2	1.9	2.5	1.5
Systolic BP	1.5	1.1	1.3	1.0	1.0	1.0	1.0	1.1	1.0
Diastolic BP	1.9	1.4	1.4	1.3	1.3	1.2	1.9	1.6	1.4