

0. BACKGROUND AND INTRODUCTION

While considerable research has been done on random-digit-dialing telephone sampling techniques, less research has been done on various techniques for weighting telephone survey data to obtain national estimates (see, for example, Cannel and Groves [1]).

During 1980 the National Center for Health Statistics (NCHS) conducted in the conterminous U.S. a random-digit-dialed telephone survey on smoking- and health-related characteristics--the National Telephone Health Interview Survey (NTHIS). Even though data were collected from only the population having a telephone in their household, estimates were desired for the entire civilian noninstitutionalized population in the U.S., including that portion of the population without a telephone in their household. The adjustments proposed to accomplish this objective are examined in this paper.

The NCHS also added to the 1980 National Health Interview Survey (NHIS) a Smoking Supplement, which by design employed a data collection instrument congruent to the one employed in the NTHIS. The NHIS is a household interview survey that employs a face-to-face data collection mode.

The first part of this paper describes the NTHIS sampling plan. Then, the fully adjusted NTHIS weighting and several alternative weighting schemes are described. Corresponding estimates based on these schemes are compared. These estimates are then compared with corresponding estimates based on the NHIS. Finally, a summary is presented.

1. NTHIS SAMPLING DESIGN

The NTHIS sampling design was based on a random-digit-dialed approach presented by Waksberg [2]. A current list of telephone Area Codes (3 digits) and corresponding Exchanges (3 digits) was obtained from the American Telephone and Telegraph Company. The list was ordered by State, geographic division, and geographic region.

Thirty national replicate random samples, each of size 100, were selected using a systematic random sampling procedure from the list of Area Codes and Exchanges. A four-digit random number was suffixed to each selected sample telephone Area Code and Exchange. A ten-digit number resulted that defined the corresponding primary telephone number for each primary sampling unit (PSU). Each such bank of 100 telephone numbers is a PSU in the NTHIS.

Each primary telephone number in the first replicate sample was dialed. If this telephone number was assigned to a household, then the primary number would be considered in scope, and the corresponding PSU would be retained in the sample.

The procedure used to generate the additional sample telephone households from a primary number was as follows: For each in scope primary telephone number (i.e., a residential telephone number including area code), 25 random two-digit

combinations were generated. The additional residential telephone numbers in the PSU were partially listed by sequentially suffixing 25 two-digit random number combinations to the first eight digits of the corresponding primary number (including Area Code). These numbers were dialed in sequence until eight additional residential telephone numbers were identified and thus selected for the sample. Attempts were made by telephone to obtain survey information from each individual 17 years of age and over in these sample telephone households. PSU's having a nonresidential primary telephone number were eliminated from the NTHIS sample.

Additional national replicates were sequentially introduced until the sample included approximately 4,000 responding households.

2. FULLY ADJUSTED NTHIS WEIGHTING SCHEME--RATIONALE AND DECISIONS

The fully adjusted record weighting scheme for the NTHIS can be formulated as a product of four factors (see figure 1).

Fully adjusted weight
= (adjustment for the probability of selection)
× (PSU-level adjustment for nonresponse)
× (adjustment for telephone coverage)
× (poststratification adjustment)

Figure 1.--Fully Adjusted NTHIS Weighting Scheme

An adjustment for the probability of sample person selection is the first factor in the fully adjusted weighting scheme. This factor decreases the weight for those sample individuals who reside in households with more than a single telephone number--these individuals have a higher probability of selection because they are associated with more than one telephone number. To reduce the variability among the weights, two was the maximum number of household telephone numbers used in determining the sample household probability of selection; however, the number of telephones had little effect on the estimates.

The second factor of the fully adjusted weighting scheme was an adjustment for household nonresponse. Even though up to 11 telephone attempts were made to contact each selected sampled telephone number, not all eligible sample households were surveyed. Most of the households in this category refused to participate.

The rationale for the second factor was that households within a single PSU were believed to be relatively homogeneous in terms of survey variables and a PSU-level adjustment for household nonresponse was proposed. Because nonresponse was believed to be more common among certain demographic classes of the population, within-household nonresponse was not addressed with a second-stage adjustment. Residual nonresponse (i.e., within household) was to be addressed in the poststratification adjustment.

The third factor in the fully adjusted record weighting scheme was an adjustment for telephone coverage by race and by geographic region. The adjustment equaled the estimated number of persons by race and region divided by the corresponding figure for the telephone population. The NHIS estimated U.S. population domain totals by age, sex, and race are consistent with those of the Census Bureau. Table 1 shows these adjustment factors vary from from 1.04 to 1.26.

Table 1.--Adjustment Factors for Telephone Coverage: 1980 NTHIS.

Adjustment Factor Region And Race	For Telephone Coverage
Northeast	
Blacks	1.1283
Races other than Black	1.0395
North Central	
Blacks	1.1080
Races other than Black	1.0413
South	
Blacks	1.2555
Races other than Black	1.0880
West	
Blacks	1.0748
Races other than Black	1.0540

The rationale for the third factor was that Thornberry and Massey [3] noted the gap between the civilian noninstitutionalized and the telephone civilian noninstitution population and also noted that the percentage of telephone coverage of the population varied according to basic socio-demographic characteristics. The coverage rates varied by region and race.

Table 2.--Poststratification Adjustment Factor According To Sex, Educational Attainment And Age: Fully Adjusted NTHIS Weighting Scheme

Sex And Age	Educational Attainment		
	<12	12	12<
	Poststratification Adjustment		
Males			
17-24 years	1.4221	1.2736	0.8659
25-44 years	1.7867	1.1206	1.0213
45-64 years	1.3440	1.2917	1.0772
65 years and over	1.5278	1.0599	0.9582
Females			
17-24 years	1.4550	1.0679	0.9329
25-44 years	1.5668	1.0144	0.8749
45-64 years	1.2064	1.0017	0.8778
65 years and over	1.5103	1.1148	1.0090

The fourth factor in the fully adjusted weighting scheme was a poststratification adjustment by age, sex, and education. This adjustment was used to adjust the estimated population totals to known population totals.

Table 1 shows that this adjustment factor varied from 1.04 to 1.26. These poststratification variables were important determinants for health-related characteristics.

The variable education may also be considered as a surrogate for the variable income, which was felt to be an important poststratification variable in a telephone survey [4]. Thornberry and Massey observed "telephone coverage increases with increasing education and income." Table 2 shows that the poststratification adjustment factors ranged from 0.9 to 1.8 in the fully adjusted weighting scheme that included adjustments for the probability of selection, household nonresponse, and telephone coverage.

3. COMPARISON OF WEIGHTING SCHEMES

The NTHIS population aggregate statistics are sums of sampling weights. Proportions are quotients of these sums. As noted, these weights were formulated as a product of factors.

The effect on percentage estimates based on the fully adjusted weighting scheme is assessed through a comparison of percentage estimated based on it with corresponding estimates based on weighting schemes where constituent factors were systematically omitted. Specifically, percentage estimates based on the fully adjusted weighting scheme are compared with those based on three similar but slightly less complex schemes. The adjustment factors in each alternative weighting scheme are shown in Figure 2.

Adjustment	Alternative Weighting Schemes				
	1 ^a	2	3	4	5
Probability of selection		X	X	X	X
Household nonresponse		X	X		
Telephone coverage		X		X	
Poststrati- fication		X	X	X	X

Figure 2.--Adjustment Factors In Alternative NTHIS Weighting Schemes

^aScheme 1 is based on unweighted data.

Each of the alternate sample weighting schemes included the adjustment factors for the probability of sample selection and poststratification with the exception of the alternative based on unweighted data. This allows evaluation of the impact of the individual adjustments on percentage estimates. Moreover, if the corresponding percentage estimates did not differ by much, then we would have some evidence that a slightly less complex estimator would suffice to produce percentage estimates.

The weighting schemes that included the proposed poststratification adjustment but without the explicit adjustment for telephone coverage are indeed adjusted for telephone coverage. In this

case, an implicit adjustment for telephone coverage is made within the poststratification cells, which are defined by sex, age, and educational attainment. In the same fashion, for example, the poststratification adjustments for weighting schemes 4 and 5 include implicit adjustments for nonresponse.

The explicit adjustment for telephone coverage is made within cells defined by race and geographic region; this adjustment effects a redistribution of the sampling weights that is different than the redistribution of the sampling weights effected by the poststratification adjustment alone. For example, under a weighting scheme with adjustments for poststratification and telephone coverage more of the sampling weights are redistributed to Black respondents in the South than under a weighting scheme with adjustment for poststratification but without an adjustment for telephone coverage--the South's telephone coverage is less than that in the other regions. Accordingly, if the survey analysis plan contained characteristics of interest defined in terms of the geographic regions or income or education (or if aggregate statistics were desired), then the fully adjusted weighting scheme, alternative 2 in Figure 2, is specifically addressing frame weaknesses.

The statistics based on the telephone survey are also compared with unpublished corresponding data from the 1980 NHIS Smoking Supplement, which was conducted during the last two quarters of the year on one third of the NHIS sample.

The 1980 NHIS Smoking Supplement employed a data collection interview instrument that was by design congruent to the interview schedule employed in the NTHIS. Nonetheless, some differences in statistics derived from these face-to-face and telephone surveys may be attributable to the differences in data collection modes (see Massey, Barker, and Moss [5]), rather than attributable to the differences in the frames and sampling designs.

4. COMPARATIVE ANALYSIS

Estimates of percentage of the population who have never smoked according to age and sex based on (1) the NHIS, (2) the NTHIS data using the fully adjusted weighting scheme (viz., alternative 2--with adjustments for the probability of selection, household nonresponse, telephone coverage, and poststratification to benchmark totals), and (3) the NTHIS using unweighted data are presented in Table 3. It should be noted that estimates of the same characteristic of interest do vary. The characteristic of interest never having smoked was selected because the characteristic was believed not to be subject to a large error due to measurement or the data collection mode.

Table 3 shows the consistency of the alternative weighted estimates for the proportion of the entire population who never smoked. These alternative estimates differ by 0.2 percentage points.

More importantly, if one assumes a design effect (Deff) (e.g., see Cochran [7]) of 1 for the NTHIS, then the difference between the NTHIS estimate of the proportion of the population 17

years and over who never smoked and the NHIS estimate based on the recommended weighting scheme of the same characteristic proportion is significant (at the 5 percent level). A Deff of 1 is an approximate value for random-digit-dialed surveys (e.g., see [1]). The actual Deff for these statistics is not yet available.

Looking further at table 3, the differences between NHIS and NTHIS estimates are significant when estimating the percentage of the population who never smoked among the following domains: males 17 years of age and over, the population 45-64 years of age, males 45-64 years of age, and males 65 years of age and over. It is possible to speculate that a larger nonresponse rate for males than for females produces a nonresponse bias. The males may be, for example, more difficult to survey at their residences. Also, the sample males who respond to the survey may have different health characteristics than those who are not surveyed.

While the estimates based on the weighted alternative schemes (alternatives 2 - 5) are consistent in the sense that they differ by a small amount, the adjustments changed the unweighted estimates in the direction away from the corresponding NHIS figure for the population. This relationship between either alternative estimate 2 or 3 and the corresponding NHIS figures for the population was observed in 14 out of the 15 domains defined by the characteristics of interest in table 3. Moreover, the one domain that this relationship does not hold is quite small--and hence the NTHIS estimate is subject to a large sampling error.

Table 4 presents the same type of internal consistency among the weighted alternative estimates; however, again, the adjustments change the estimate in the direction away from the NHIS figure in 9 out of the 10 domains defined by the characteristics of interest. Again, the only domain in which the NTHIS estimate of the characteristic of interest based on an alternative weighting scheme is closer to the corresponding NHIS figures is small in size; hence, the estimate is subject to a large sampling error.

Some evidence exists that response rates differ according to smoking status, which produce a response bias in the presented NTHIS data. Evidence consistent with this speculation was previously presented by Massey, Barker, and Hsuung [6]. Sample persons who are nonsmokers may be less likely to participate in a telephone survey on smoking than sample persons who are smokers--especially when nonsmokers are told the survey's focus. Nonsmokers may have very little interest in smoking.

As another means to explain these relationships, the relationship between one other set of corresponding statistics was examined. The data presented in tables 3 and 4 may be used to compare estimates of the proportion of the population who never smoked for the domain defined by telephone civilian noninstitutionalized population 17 years of age and older in the conterminous U.S. based on data from the NHIS and based on unweighted NTHIS data. Using these domains, geographic and telephone status factors do not confound any detected differences in the estimates of various characteristics of interest.

Furthermore, if one is willing to assume the NTHIS sampling design results in a sample that is essentially a simple random sample of the civilian noninstitutionalized population 17 years and over that reside in residences with a telephone (the domain) the percentages based on unweighted NTHIS data should theoretically estimate in an unbiased fashion the characteristics of interest for this domain or any subdomain.

For 11 out of the 15 domains of interest defined in table 3, however, the estimates of the proportion of the domain of interest that never smoked based on unweighted NTHIS data are less than the corresponding NHIS figure for the corresponding telephone population; however, within the 25-44 years of age category, the percentage of the total population and the percentage by sex show the percentage of never smoked based on unweighted NTHIS data larger than the corresponding NHIS figures for the telephone population. For 8 out of the 10 domains of interest defined in table 4, the NTHIS estimates based on unweighted data are less than the corresponding NHIS figures for the telephone population. While it is possible that some of these individual relationships are not significant, the fact that they are so prevalent throughout tables 3 and 4 establishes cogent argument for the significance of difference of the figures.

Accordingly, the alternative weighting schemes yield data that are internally consistent, but yield data that seems to be adjusted away from comparable NHIS figures for the telephone population. Also, unlike the data presented in tables 3 and 4, virtually no difference for corresponding characteristics of interest between alternatives 2 and 3 was observed (maximum of 0.1 percentage points).

Few differences were noted in percent estimates of specific characteristics of interest based on weighted data. This paper does not include estimates of characteristics of interest for the geographic regions or for specific income categories; estimates for these characteristics of interest based on data weighted according to the various schemes are expected to show more variation than the estimates for the more basic characteristics of interest presented in this paper. For example, the estimated percentage of Blacks in the South probably will be affected by either the inclusion or the exclusion of the adjustment for telephone coverage in the South. Nonetheless, we recommend the use of the fully adjusted weighting scheme as the scheme that is most credible.

5. Summary

This paper presents data on the effect of weighting adjustments on estimates from a random-digit-dialed telephone survey. The fully adjusted weighting scheme encompassed adjustments for (1) the probability of sample selection, (2) household response at the PSU level, (3) tele-

phone coverage by race and region, and (4) post-stratification by age, sex, and education. The estimated percentages for characteristics of interest presented in this paper did not vary much as long as the weighting scheme employed included adjustments for probability of selection and poststratification.

The use of the fully adjusted weighting scheme, nonetheless, is recommended in developing estimates of characteristics of interest, especially those for aggregate statistics or statistics affected by race, region, or income. Estimates for many of these characteristics of interest are not examined in this paper.

The use of demographic characteristics and education attainment in the weighting schemes for data from a random-digit-dialed telephone survey did not explain the differences between fully adjusted NTHIS estimates and the corresponding NHIS estimates. It is speculated that smoking statistics from the NTHIS are subject to a response bias.

References

- [1] Cannel, Charles F. and Robert M. Groves. The Effect of Post Survey Adjustments from the Health Interview Survey and the Survey Research Center Telephone Survey: A report to the National Center for Health Statistics--Contract No. 233-78-2034--September 1981.
- [2] Waksberg, Joseph. Sampling Methods for Random Digit Dialing. Journal of the American Statistical Association, March 1978.
- [3] Thornberry, Owen T. and James T. Massey. "Correcting for Undercoverage Bias in Random Digit Dialed National Health Surveys". 1978 Proceeding of the Survey Research Methods Section of the American Statistical Association.
- [4] Personal communication with Joseph Waksberg.
- [5] Massey, James T., Peggy R. Barker, and Abigail J. Moss. "Comparative Results of a Face-to-Face and Telephone Interview in a Survey on Cigarette Smoking." Presented at the American Public Health Association Meeting, November 1980.
- [6] Massey, James T., Peggy R. Barker, and Sue Hsuing. "An Investigation of Response in a Telephone Survey". 1981 Proceedings of the Survey Research Methods Section of the American Statistical Association.
- [7] Cochran, William G. Sampling Techniques, 1980.

Table 3.--Percent Of Population 17 Years Of Age Or Older Who Never Smoked
According To Age and Sex: 1980 NHIS and 1980 NTHIS.

Age and Race	Percent Never Smoked						
	Alternative 1980 NTHIS Estimates					1980 NHIS	
	1	2	3	4	5	All Hous. ^e	Tel. Hous. ^f
	Unweighted	[P+NR +TC+B] ^a	[P+NR+B] ^b	[P+TC+B] ^c	[P+B] ^d		
All 17+ years							
Both sexes	45.6	44.7	44.6	44.6	44.5	46.4	46.4
Males	34.9	33.3	33.3	33.3	33.2	35.7	35.5
Females	54.3	54.8	54.7	54.8	54.6	55.9	56.1
17-24 years							
Both sexes	58.5	57.4	57.3	57.6	57.5	59.1	60.7
Males	59.2	57.3	57.3	57.6	57.6	58.1	59.4
Females	57.8	57.5	57.2	57.6	57.3	60.0	62.0
25-44 years							
Both sexes	44.0	41.9	41.9	41.9	41.9	42.5	42.7
Males	35.0	32.8	32.8	32.9	32.9	33.6	33.9
Females	51.3	50.5	50.4	50.4	50.3	50.8	50.9
45-64 years							
Both sexes	36.1	34.9	34.8	34.7	34.7	37.9	37.8
Males	18.9	18.6	18.6	18.0	18.0	22.3	22.3
Females	49.2	49.8	49.8	50.1	50.0	52.1	51.5
65+ years							
Both sexes	50.8	52.3	52.2	51.9	51.7	54.9	53.8
Males	25.3	28.0	27.8	27.9	27.7	34.7	32.7
Females	68.3	69.4	69.2	68.7	68.5	69.0	68.2

^a Alternative estimate 2 is based on data adjusted for the probability of selection (P), for household nonresponse (NR), for telephone coverage (TC), and poststratification to benchmark totals (B).

^b Alternative estimate 3 is based on data adjusted for the probability of selection (P), for household nonresponse (NR), and poststratification to benchmark totals (B).

^c Alternative estimate 4 is based on data adjusted for the probability of selection (P), telephone coverage (TC), and poststratification to benchmark totals (B).

^d Alternative weight 5 is based on data adjusted for the probability of selection (P) and poststratification to benchmark totals (B).

^e NHIS Smoking Supplement data based on unpublished estimates for the civilian noninstitutionalized population (viz., persons in all households) in the U.S.

^f NHIS Smoking Supplement data based on unpublished estimates for the telephone civilian noninstitutionalized population in the conterminous U.S.

Table 4.--Percent Of Population 17 Years Of Age Or Older Who Never Smoked According To Age and Race: 1980 NHIS and 1980 NTHIS.

Age and Race	Percent Never Smoked						
	Alternative 1980 NTHIS Estimates					1980 NHIS	
	1	2	3	4	5	All Hous. ^e	Tel. Hous. ^f
	Unweighted	[P+NR+TC+B] ^a	[P+NR+B] ^b	[P+TC+B] ^c	[P+B] ^d		
All 17+ years							
White	44.9	43.8	43.8	43.7	43.7	45.5	45.5
Black	50.0	49.2	48.9	50.0	49.7	51.0	52.0
17-24 years							
White	57.4	55.9	55.9	56.1	56.1	57.8	58.9
Black	63.7	64.4	64.0	64.4	63.9	65.0	71.0
25-44 years							
White	43.5	41.4	41.4	41.4	41.3	41.6	41.9
Black	43.3	40.6	40.5	41.9	41.8	45.3	45.6
45-64 years							
White	35.8	34.6	34.6	34.4	34.4	37.4	37.2
Black	40.1	37.4	37.3	38.3	38.2	39.6	41.0
65+ years							
White	49.7	51.0	51.0	50.5	50.5	53.9	53.0
Black	65.7	67.3	66.8	67.1	66.5	63.5	61.4

^aAlternative estimate 2 is based on data adjusted for the probability of selection (P), for household nonresponse (NR), for telephone coverage (TC), and poststratification to benchmark totals (B).

^bAlternative estimate 3 is based on data adjusted for the probability of selection (P), for household nonresponse (NR), and poststratification to benchmark totals (B).

^cAlternative estimate 4 is based on data adjusted for the probability of selection (P), telephone coverage (TC), and poststratification to benchmark totals (B).

^dAlternative weight 5 is based on data adjusted for the probability of selection (P) and poststratification to benchmark totals (B).

^eNHIS Smoking Supplement data based on unpublished estimates for the civilian noninstitutionalized population (viz., persons in all households) in the U.S.

^fNHIS Smoking Supplement data based on unpublished estimates for the telephone civilian noninstitutionalized population in the conterminous U.S.