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# Improving Public Health Surveillance Using a Dual-Frame Survey of Landline and Cell Phone Numbers

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To meet challenges arising from increasing rates of noncoverage in US landline-based telephone samples due to cell-phone-only households, the Behavioral Risk Factor Surveillance System (BRFSS) expanded a traditional landline-based random digit dialing survey to a dual-frame survey of landline and cell phone numbers. In 2008, a survey of adults with cell phones only was conducted in parallel with an ongoing landline-based health survey in 18 states. The authors used the optimal approach to allocate samples into landline and cell-phone-only strata and used a new approach to weighting state-level landline and cell phone samples. They developed logistic models for each of 16 health indicators to examine whether exclusion of adults with cell phones only affected estimates after adjustment for demographic characteristics. The extents of the potential biases in landline telephone surveys that exclude cell phones were estimated. Biases resulting from exclusion of adults with cell phones only from the landline-based survey were found for 9 out of the 16 health indicators. Because landline noncoverage rates for adults with cell phones only continue to increase, these biases are likely to increase. Use of a dual-frame survey of landline and cell phone numbers assisted the BRFSS efforts in obtaining valid, reliable, and representative data.

data collection; epidemiologic methods; population surveillance; sampling studies; selection bias; telephone

Abbreviations: AAPOR, American Association for Public Opinion Research; BRFSS, Behavioral Risk Factor Surveillance System; HIV, human immunodeficiency virus; PSA, prostate-specific antigen; RDD, random digit dialing.

The Behavioral Risk Factor Surveillance System (BRFSS) is the world's largest ongoing, list-assisted random digit dialing (RDD) landline telephone-interview health survey system, tracking health conditions and risk behaviors throughout the United States yearly since 1984. With support from the Centers for Disease Control and Prevention, the BRFSS is conducted by all 50 state health departments, as well as those in the District of Columbia, Puerto Rico, Guam, and the US Virgin Islands. Every month, data on behaviors that place health at risk, clinical preventive health practices, and access to and use of health-care services are collected from a randomly selected, representative sample of adults aged 18 years or older.

For the past several decades, RDD telephone sampling of households with landline telephones has provided a cost-efficient strategy for conducting surveys of the US population. However, as the percentage of cell-phone-only households (households with no landline telephone) continues to grow, the validity of the basic RDD landline sampling model used by most survey organizations has become open to question (1–10). One study found that for the period covering January through June 2008, 17.5% of households had only cell phones and 16.1% of US adults reported living in cell-phone-only households (1). Nearly two-thirds (63.1%) of all adults living with unrelated roommates, 31.4% of adults aged 18–24 years, and 35.7% of adults aged 25–29 years lived in cell-phone-only households (1). These adults are not covered by current RDD landline sampling procedures, which exclude telephone exchanges used for cell phones, and the percentages are trending upwards. These are some of the same groups that are increasingly underrepresented in current RDD landline telephone surveys (11, 12).

In 2008, to address the trend of increasing prevalence of cell-phone-only households and the corresponding potential

for bias in estimates from surveys that sample only from landline frames, the BRFSS initiated a pilot study in 18 states that involved expanding the traditional landline-based RDD survey to a dual-frame survey of landline and cell phone numbers. This pilot study also allowed for assessment of the feasibility of conducting surveys via sampled cell phone numbers, as well as research on the similarities and differences between respondents interviewed by landline phone and those interviewed by cell phone. In the present study, we calculated the noncoverage bias in landline telephone surveys that exclude cell phones and examined differences in estimates between the 2 survey samples for 16 health indicators.

## MATERIALS AND METHODS

Our survey of adults with cell phones only was conducted in parallel with ongoing, monthly landline RDD BRFSS data collection. Landline samples provide coverage of adults living in US households with only a landline telephone, as well as adults with cell phones living in landline households (dual-service adults). One adult is randomly selected from each sampled landline household. Detailed information about the BRFSS landline telephone survey design, methods, and questionnaire are available at www.cdc.gov/brfss.

### Cell phone survey

The cell-phone-only sample of adults was selected through screening of a sample of cell phone numbers, because cell-phone-only adults cannot be identified in advance of sampling. The population of adults living in households with telephone service can be divided into 2 primary strata: landline and cell-phone-only (13). Although the majority of the adult population is contained in the landline stratum, the proportion of the population in the cell-phone-only stratum has been rapidly growing. Several factors, including the screening, make the cost of a cell-phone-only interview higher than that of a landline interview. In this situation, the allocation of the total sample to the 2 strata can be determined using the optimum allocation, which seeks to minimize the variance for a specified total cost (14, 15). The optimum allocation, in terms of the proportion of the total sample that should come from the cell-phone-only stratum, can be expressed as (16)

$$\frac{p}{p + \left(1 - p\right)\sqrt{\frac{C_{\text{cell-only}}}{C_{\text{landline}}}}}.$$

In this formula, $p$ equals the estimated proportion of adults in a state that use only a cell phone, $C_{\text{cell-only}}$ is the cost of conducting a cell-phone-only interview, and $C_{\text{landline}}$ is the cost of conducting a landline RDD interview. Based on the 2007 BRFSS pilot study and other cost estimates that have been reported, the cost ratio of $C_{\text{cell-only}}$ to $C_{\text{landline}}$ is approximately 5 (6). In the last half of 2008, investigators with the National Health Interview Survey reported that 20% of adults in the United States used cell phones only (2). Using $p = 0.20$, we obtain the allocation that approximately 10% of the interviews in a state should be with cell-phone-only adults and 90% should be with landline sample adults.

The universe for the pilot study consisted of all noninstitutionalized adults aged 18 years or older living in the United States. Cell telephone numbers were sampled and screened for adults living within one of the 18 pilot states and in private residences with no landline telephones in the household. One complication of sampling cell phone numbers for a state-based survey is that cell phone subscribers can retain their phone number when moving to a different city or state. Consequently, subscribers are sometimes sampled from geographic areas where they no longer live, or state residents whose cell phone has a different state's area code might not be sampled from the current state. In our study, when such an out-of-state number was reached, the interview continued and the data were transferred to the appropriate state, provided that the respondent's current state was one of the 18 participating in the pilot study. Respondents meeting this requirement and the other eligibility criteria (i.e., reached on a cell phone, living in a private residence, and 18 years or older) were then asked whether they also had a landline telephone, described as a ''regular'' telephone in the home that was connected to outside telephone lines through a cable or cord and was used for making or receiving calls. Only adults without landline telephone service were interviewed. Our sampling model treats the cell phone as a personal communication device, and therefore, unlike landline telephone samples, no random selection of an adult from the household takes place.

The 2008 BRFSS core questionnaire was used for the pilot study and was programmed using a computer-assisted telephone interviewing system. Interviews were conducted in English unless respondents preferred to complete the interview in Spanish, in which case a bilingual interviewer conducted the interview using a translated questionnaire.

We developed a contacting and interviewing protocol based on a previous study of cell phone coverage (6). Before beginning each interview, interviewers established that the respondent was able to communicate with the interviewer safely and without distractions. For example, if a respondent reported that he or she was driving a car or engaging in some other activity that could divert the respondent's attention from the interview, the interviewer set an appointment for a later date or simply terminated the call, letting the respondent know that he or she would call back at a more convenient time. If a respondent asked not to be called on his or her cell phone, interviewers would attempt to avert a refusal by asking for another telephone number (including landline numbers) at which the respondent could be contacted or if there was a better time for him or her to take a call via cell phone (e.g., when incoming calls would not incur a cost). No further attempt would be made to contact respondents who did not provide this information. However, people giving more general, nonhostile refusals were recontacted once for a conversion attempt. A toll-free hotline that respondents could call to verify the legitimacy of the study or to ask for any other assistance was made available.

Data collection was carried out in January through December 2008. Details on the procedures of data collection via cell phone have been previously released (6).

### Landline telephone survey

In addition to our data from cell-phone-only respondents, we used traditional BRFSS survey data from the 18 participating states for the months of January through December 2008 in this analysis. Additional questions were added to the landline telephone survey to determine the type of telephone access in the household (both landline and cell phone or landline only) and to obtain information for combining the data with the cell phone data and developing proper weights (17).

### Analysis

*Weighting and postsurvey adjustments.* The 2008 BRFSS combined sample included RDD landline interviews conducted in the 18 states and the interviews conducted with adults in the cell phone sample who were screened for the absence of a working landline telephone used for calls in their households. Thus, the combined sample comprised 2 key strata: adults with landline telephone service and adults who had only a cell phone. The weighting method for the 2008 BRFSS combined sample involved the 3 main steps detailed below.

The design weight of each completed BRFSS RDD landline interview in a state represents the product of 3 factors: 1) the reciprocal of the selection probability of the telephone number, 2) the number of adults in the household, and 3) the reciprocal of the number of voice-use landline telephone numbers in the household. The design weight for the cell-phone-only adults interviewed in the cell phone sample in each state equals the reciprocal of the probability of selection of the cell telephone number.

The second step is to construct telephone usage group population control totals. RDD landline interviews can be combined with the cell-phone-only interviews in each state and poststratified to state-level population control totals of age by gender by race/ethnicity or region by age by gender by race/ethnicity. For the state-based BRFSS samples, we used a model-based approach to develop state telephone usage group estimates based on the 2007 National Health Interview Survey (18). The National Health Interview Survey data allows adults to be assigned to a telephone usage group: 1) landline service only, 2) both landline and cell telephone service, 3) cell phone service only, or 4) no telephone service. Using telephone usage group as the dependent variable, we fitted a national multinomial logistic regression model to the 2007 National Health Interview Survey using sociodemographic variables as the predictors. The resulting model was then applied to the adults in each state in the 2005–2007 American Community Survey (19, 20). The predicted probabilities of membership in the telephone usage groups were then used to develop estimates of the size of the telephone usage groups in each state (19, 20).

The last step is to calculate combined sample final weights. We combined all 2008 BRFSS respondents from the 2 samples in each state. The weighting procedure known as ''raking'' (21) was used to weight the respondents in each state to population control totals for 2 margins: 1) the standard BRFSS age by gender, age by gender by race/ethnicity, region by age by gender, or region by age by gender by race/ethnicity poststratification variable, with population control totals developed by Claritas, Inc. (San Diego, California), and 2) population control totals for the 3 relevant telephone usage groups (landline only, both landline and cell phone, and cell phone only), with control total estimates developed from the 2005–2007 American Community Survey as described in the second step. The final weights for the combined sample were calculated using a SAS raking macro (22) with weight trimming allowed during the raking iterations.

*Response rate calculations.* To maximize comparability between the landline and cell phone surveys, we used response rate calculations recommended by the American Association for Public Opinion Research (AAPOR) (23). For the BRFSS landline telephone survey, the original BRFSS disposition codes were mapped to the AAPOR-specified codes and response rates were calculated using AAPOR Response Rate Formula 4 (23). As has been previously noted (24), however, interviewing by cell phone requires additional case disposition codes beyond those recommended by AAPOR for landline surveys to deal with some of the unique situations encountered—such as when a respondent is in an area with limited or no cell phone service, the connection fails for some unknown reason, or the interviewer receives one of a variety of operator messages.

*Prevalence estimates.* We used respondent self-reports to assess the prevalence of 16 important health and risk behavior measures: self-evaluation of health status, access to health-care coverage, nonreceipt of health care due to cost, asthma, diabetes, coronary heart disease, obesity, current smoking, binge drinking, physical activities, human immunodeficiency virus (HIV) testing, teeth cleaning, influenza vaccination, mammography, prostate-specific antigen (PSA) testing, and sigmoidoscopy examination (see www.cdc.gov/brfss for details).

*Analysis procedure.* We conducted all analyses using SAS, version 9.1 (SAS Institute, Inc., Cary, North Carolina) survey procedures to account for the complex survey sampling design. We used 95% confidence intervals to determine whether differences were statistically significant. The analysis was conducted in 3 parts. First, we examined the relation between survey approaches and demographic characteristics of respondents through pairwise contingency tables. Next, a similar approach was used to examine the bivariate relation between survey approaches and the 16 health condition and risk behavior measures. We developed logistic models for each of the health indicators to examine whether survey approach affected responses after adjusting for the impact of demographic characteristics such as age, gender, educational level, marital status, and employment status. Finally, we estimated the potential bias in landline telephone surveys that exclude cell phones using the metric of

$$\text{Relative Bias} = \frac{\frac{N_2}{N}(\bar{Y}_1 - \bar{Y}_2)}{\bar{Y}_1},$$

where the numerator is the degree of noncoverage bias, which is a function of 2 factors: the percentage of cell-phone-only adults in the adult population and how much the respondents in the landline survey and those in the cell phone survey differ with regard to survey variables of interest (14, 25). Relative bias assesses the percentage by which the survey variables of interest would be overestimated or underestimated if the estimates were based only on the landline survey data. Values above 0.40 for relative bias changed the 95% level initially established for confidence intervals (14), which may cause wrong inferences to be drawn.

## RESULTS

### Response rates

Overall, a sample of 23,397 telephone numbers across the 18 states was drawn from a cellular sampling frame. The sample was obtained from a telephone survey sampling vendor. The vendor created the sampling frame of 10-digit telephone numbers located in dedicated cellular 1,000 banks (e.g., 617-417-7000 to 617-417-7999) (13). We obtained a total of 5,794 completed or partially completed cell phone surveys from the 18 states. Overall and state-specific response rates for the surveys, which we calculated using AAPOR Response Rate Formula 4 (23), are provided in Table 1. For all states except Mississippi, response rates were modestly lower in the cell phone survey than in the landline phone survey. Out of 5,794 cases from the cell phone survey, 433 cases (7.5%) were living in group quarters. These cases were excluded from these analyses because they did not fit the BRFSS household survey definition. Of the remaining 5,361 cases, 158 (2.9%) had an out-of-state cell phone number.

### Demographic characteristics

The distributions of several demographic characteristics among cell phone survey respondents differed significantly from those of landline telephone survey respondents (Table 2), including the percentages of respondents who were male (cell phone, 59.4%; landline, 46.7%; $P < 0.001$); were non-Hispanic white (cell phone, 57.3%; landline, 66.8%; $P < 0.001$); were 18–34 years of age (cell phone, 64.2%; landline, 24.8%; $P < 0.001$); were not working or retired (cell phone, 16.2%; landline, 36.6%; $P < 0.001$); were never married (cell phone, 43.8%; landline, 17.3%; $P < 0.001$); and had an annual household income of less than $35,000 (cell phone, 48.5%; landline, 31.9%; $P < 0.001$). No significant differences in education were observed between these 2 groups.

### Key health conditions and risk factor indices

We found that the landline survey produced significantly higher prevalence estimates than the cell phone survey for any kind of health-care coverage, ever having angina or coronary heart disease, being obese, having teeth cleaned, having an influenza shot, having a mammogram, having a PSA test, and having a sigmoidoscopy examination (Table 3). In contrast, the respondents in the cell phone study reported significantly higher prevalence estimates than those in the landline study for self-rated health status of ''feeling good or better,'' not receiving health care due to cost, current smoking, binge drinking, engaging in physical activity, and ever being tested for HIV. These findings are not surprising, given the difference in demographic distribution between the 2 survey approaches.

Even after we used logistic regression to adjust for other potential confounders, including age, gender, educational level, marital status, and employment status, most of these differences persisted. When the respondents in the cell phone survey were compared with those in the landline survey, the odds of a ''yes'' response were lower by 45% for having any kind of health care coverage, by 37% for having teeth cleaned in the past 12 months, by 17% for having a flu shot in the past 12 months, by 40% for ever having a PSA test, and by 38% for ever having a sigmoidoscopy examination. In contrast, the odds of a ''yes'' response were greater by 39.2% for not receiving health care due to cost, by 44.8% for being a current smoker, by 39.0% for being a binge drinker, and by 25.6% for ever being tested for HIV.

For 4 of 9 health risk and health condition indices that remained different between surveys after controlling for demographic factors, the relative biases were negative, indicating that the landline survey underestimated prevalence by 9.2% for not receiving health care due to cost, by 10.3% for being a current cigarette smoker, by 14.8% for being a binge drinker, and by 5.1% for ever being tested for HIV. In contrast, 5 relative biases had positive values, indicating that the landline survey overestimated prevalence by 2.9% for having any kind of health care coverage, by 3.3% for having teeth cleaned in the past 12 months, by 6.4% for having a flu shot in the past 12 months, by 3.5% for ever having a PSA test, and by 1.8% for ever having a sigmoidoscopy examination.

## DISCUSSION

Similar to some previous studies (6, 9, 26–28), our state-based cell phone study showed that conducting surveys by sampling cell phone numbers is feasible, but it is costly and produces relatively low rates of participation. Response rates varied by state but were in line with those reported in other cell phone studies (5, 6).

The study also verified at the state level what other investigators have found in national surveys with regard to the significant differences between adults with cell phones only and those with other types of telephone access. Relative to adults with landlines, cell-phone-only adults were more likely to be binge drinkers and current smokers, to engage in regular physical activity, and to have had an HIV test. They were more likely to have an unmet need for medical care due to cost and were less likely to have any kind of

**Table 1.** Rates of Response to the Behavioral Risk Factor Surveillance System Survey, by State and Survey Mode, 2008

| State | Cell Phone Only | | Landline | |
|---|---|---|---|---|
| | No. of Respondents | Response Rate, %[a] | No. of Respondents | Response Rate, %[a] |
| California | 286 | 14.21 | 11,598 | 36.83 |
| Connecticut | 236 | 24.27 | 6,155 | 39.17 |
| Georgia | 285 | 32.98 | 5,716 | 54.43 |
| Hawaii | 337 | 31.52 | 6,446 | 47.42 |
| Iowa | 250 | 55.86 | 6,012 | 59.30 |
| Louisiana | 304 | 36.02 | 6,182 | 47.82 |
| Massachusetts | 271 | 28.82 | 20,581 | 47.38 |
| Michigan | 260 | 38.75 | 9,453 | 54.09 |
| Minnesota | 437 | 44.31 | 4,287 | 60.46 |
| Mississippi | 278 | 56.87 | 7,949 | 49.04 |
| Missouri | 170 | 40.62 | 5,158 | 55.50 |
| Montana | 205 | 51.03 | 6,846 | 47.75 |
| Nebraska | 630 | 38.39 | 16,255 | 64.38 |
| New York | 256 | 25.98 | 7,915 | 38.66 |
| South Carolina | 292 | 36.53 | 10,202 | 59.50 |
| Virginia | 227 | 30.35 | 5,310 | 41.05 |
| Washington | 794 | 21.88 | 22,532 | 49.37 |
| Wisconsin | 276 | 42.68 | 7,075 | 57.55 |
| Total | 5,794 | 31.04 | 165,672 | 49.14 |

[a] Response rates were calculated using American Association of Public Opinion Research Response Rate Formula 4 (23).

health-care coverage. They were also less likely to be obese and less likely to use preventive health-care services, including having teeth cleaned and having a flu shot in the past 12 months and ever having a mammogram, a Papanicolaou test, a PSA test, or a sigmoidoscopy examination.

The differences we found in demographic characteristics of the respondents by telephone mode and in the health and risk behavior measures were similar to those reported elsewhere (6, 9). The fact that these groups differed significantly even after we controlled for other potential confounders (e.g., age, gender, race, education, marital status, and household income) supports previous findings of this kind. For most of these health-related behaviors and measures of health-care access, the potential coverage bias due to exclusion of cell-phone-only adults was statistically significant even after adjustment for demographic differences. Among the 16 measures examined, the potential bias would be greatest in the context of alcohol consumption surveys of adults. A landline survey could be expected to underestimate the prevalence of binge drinking by 15.6%. The prevalence of current smoking was underestimated by 10.9%, not receiving medical care due to cost by 10.2%, and ever being tested for HIV by 4.7%. In contrast, cell-phone-only adults were less likely to have ever used preventive health-care services. A landline survey could be expected to overestimate the prevalence of having teeth cleaned by 3.2%, having a flu shot by 6.8%, ever having a mammogram by 6.2%, and ever having a PSA test by 3.4%. The remaining measures of potential coverage bias did not exceed 2%. As the percentage of cell-phone-only households continues to grow, we can expect these trends to continue. We conclude that using a dual-frame survey of landline and cell phone numbers is now a necessity if surveys carried out by telephone are to provide valid, reliable, and representative data.

Another explanation for some of the differences in health conditions and risk factors may be mode effects: That is, adults may answer questions differently on a landline phone in the household than they do on a cell phone in a location inside or outside the household. At issue is the degree to which persons interviewed by cell phone are ''cognitively engaged'' in the interview and not being distracted by other activities or stimuli. Cell phones are one of many modern tools that facilitate the multitasking so prominent in society today. Not only do researchers need to be concerned about issues of respondent safety (e.g., potentially interviewing someone who is driving), they also need to be concerned about how respondents answer questions while engaged in other activities, such as shopping, being in a restroom or outdoors, or dining in a restaurant, as well as the transmission voice quality. While there is only limited research concerning the mode effect of cell phone data collection versus landline data collection, Kennedy concluded that ''there is no evidence to suggest that all or even most data gathered by cell phone are of poorer quality than their landline counterpart would be'' (29). We also have limited information about the conditions in which respondents find themselves when

**Table 2.** Demographic Characteristics of Respondents to the Behavioral Risk Factor Surveillance System Survey, by Survey Mode, 2008

| Demographic Characteristic | Landline ($n$ = 165,672) | | | Cell Phone Only ($n$ = 5,361) | | | Landline and Cell Phone ($n$ = 171,033) | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. | % | Weighted % | No. | % | Weighted % | No. | % | Weighted % |
| Gender*,[a] | | | | | | | | | |
| Male | 62,335 | 37.6 | 46.7 | 2,819 | 52.6 | 59.4 | 65,154 | 38.1 | 48.7 |
| Female | 103,337 | 62.4 | 53.3 | 2,542 | 47.4 | 40.6 | 105,879 | 61.9 | 51.3 |
| Ethnicity* | | | | | | | | | |
| White | 129,881 | 78.4 | 66.8 | 3,722 | 69.4 | 57.3 | 133,603 | 78.1 | 65.3 |
| Black | 13,878 | 8.4 | 9.6 | 558 | 10.4 | 13.1 | 14,436 | 8.4 | 65.3 |
| Hispanic | 9,132 | 5.5 | 14.7 | 501 | 9.3 | 18.4 | 9,633 | 5.6 | 65.3 |
| Asian | 4,245 | 2.6 | 4.2 | 210 | 3.9 | 4.9 | 4,455 | 2.6 | 65.3 |
| Other | 6,732 | 4.1 | 3.8 | 344 | 6.4 | 5.9 | 7,076 | 4.1 | 65.3 |
| Unknown | 1,804 | 1.1 | 0.8 | 26 | 0.5 | 0.4 | 1,830 | 1.1 | 65.3 |
| Age, years* | | | | | | | | | |
| 18–24 | 5,739 | 3.5 | 10.3 | 1,175 | 21.9 | 28.1 | 6,914 | 4.0 | 13.1 |
| 25–34 | 15,294 | 9.2 | 14.5 | 1,701 | 31.7 | 36.1 | 16,995 | 9.9 | 17.9 |
| 35–44 | 24,699 | 14.9 | 19.5 | 928 | 17.3 | 16.7 | 25,627 | 15.0 | 19.0 |
| 45–54 | 34,584 | 20.9 | 20.8 | 820 | 15.3 | 11.3 | 35,404 | 20.7 | 19.3 |
| 55–64 | 36,012 | 21.7 | 16.2 | 510 | 9.5 | 5.4 | 36,522 | 21.4 | 14.5 |
| ≥65 | 49,344 | 29.8 | 18.8 | 227 | 4.2 | 2.5 | 49,571 | 29.0 | 16.2 |
| Education | | | | | | | | | |
| Less than high school | 15,618 | 9.4 | 11.3 | 527 | 9.8 | 12.2 | 16,145 | 9.4 | 11.5 |
| High school | 48,971 | 29.6 | 27.1 | 1,487 | 27.7 | 26.4 | 50,458 | 29.5 | 27.0 |
| More than high school | 100,467 | 60.6 | 60.9 | 3,338 | 62.3 | 61.1 | 103,805 | 60.7 | 60.9 |
| Unknown | 616 | 0.4 | 0.6 | 9 | 0.2 | 0.4 | 625 | 0.4 | 0.6 |
| Annual household income* | | | | | | | | | |
| <$15,000 | 15,148 | 9.1 | 9.3 | 685 | 12.8 | 16.2 | 15,833 | 9.3 | 10.4 |
| $15,000–$34,999 | 42,967 | 25.9 | 22.6 | 1,804 | 33.7 | 32.3 | 44,771 | 26.2 | 24.1 |
| $35,000–$49,999 | 22,801 | 13.8 | 12.5 | 820 | 15.3 | 14.5 | 23,621 | 13.8 | 12.8 |
| ≥$50,000 | 63,981 | 38.6 | 44.5 | 1,635 | 30.5 | 29.2 | 65,616 | 38.4 | 42.1 |
| Unknown | 20,775 | 12.5 | 11.2 | 417 | 7.8 | 7.8 | 21,192 | 12.4 | 10.6 |
| Employment* | | | | | | | | | |
| Employed for wages | 73,718 | 44.5 | 49.6 | 3,507 | 65.4 | 65.0 | 77,225 | 45.2 | 52.0 |
| Self-employed | 14,782 | 8.9 | 9.0 | 455 | 8.5 | 9.1 | 15,237 | 8.9 | 9.0 |
| Not working/retired | 73,666 | 44.5 | 36.6 | 1,016 | 19.0 | 16.2 | 74,682 | 43.7 | 33.3 |
| Student | 2,743 | 1.7 | 4.1 | 373 | 7.0 | 9.2 | 3,116 | 1.8 | 4.9 |
| Unknown | 763 | 0.5 | 0.8 | 10 | 0.2 | 0.5 | 773 | 0.5 | 0.7 |
| Marital status* | | | | | | | | | |
| Married/committed relationship | 95,313 | 57.5 | 64.3 | 2,230 | 41.6 | 38.4 | 97,543 | 57.0 | 60.2 |
| Divorced/separated/widowed | 48,850 | 29.5 | 18.0 | 1,124 | 21.0 | 17.6 | 49,974 | 29.2 | 17.9 |
| Never married | 20,803 | 12.6 | 17.3 | 1,992 | 37.2 | 43.8 | 22,795 | 13.3 | 21.5 |
| Unknown | 706 | 0.4 | 0.3 | 15 | 0.3 | 0.3 | 721 | 0.4 | 0.3 |

*$P < 0.01$.

[a] Difference in responses between landline and cell phone surveys was statistically significant. Data were weighted to account for the sample design.

they are taking part in an interview by cell phone. One survey found that most cell phone interviews were conducted indoors (89%), with 70% occurring in the respondent's home (30). Interviewers, however, rated 32% of the cell phone respondents interviewed outdoors as being somewhat/very distracted by ''noise or other things happening around'' as compared with 17% of respondents interviewed indoors (30).

**Table 3.** Prevalence Estimates for Various Health Conditions and Behavioral Risk Factors in the Behavioral Risk Factor Surveillance System, by Survey Mode, and Adjusted Odds Ratios for Comparison of Survey Modes, 2008

| Health Condition or Risk Factor | Prevalence Estimate[a] | | | | | | $\chi^2$ *P* Value[b] | Adjusted Odds Ratio[c] | 95% CI | Relative Bias, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | Landline and Cell Phone (*n* = 171,033) | | Landline (*n* = 165,672) | | Cell Phone Only (*n* = 5,361) | | | | | |
| | % | 95% CI | % | 95% CI | % | 95% CI | | | | |
| Self-rated health status of "feeling good or better" | 82.7 | 82.3, 83.1 | 82.0 | 81.6, 82.4 | 86.6 | 85.1, 88.0 | <0.01 | 0.932 | 0.804, 1.080 | |
| Any kind of health-care coverage | 83.7 | 83.2, 84.2 | 86.2 | 85.8, 86.6 | 70.4 | 68.4, 72.4 | <0.01 | 0.550* | 0.490, 0.617 | 2.90 |
| Not receiving health care due to cost | 15.0 | 14.6, 15.5 | 13.8 | 13.4, 14.1 | 21.8 | 20.0, 23.5 | <0.01 | 1.392* | 1.236, 1.567 | −9.17 |
| Ever having angina or coronary heart disease | 4.2 | 4.0, 4.4 | 4.6 | 4.4, 4.8 | 1.9 | 1.3, 2.5 | <0.01 | 0.991 | 0.717, 1.370 | |
| Ever having asthma | 14.3 | 13.9, 14.7 | 14.0 | 13.7, 14.4 | 15.6 | 14.0, 17.1 | <0.05 | 1.003 | 0.884, 1.137 | |
| Obese (body mass index[d] ≥30) | 26.4 | 25.9, 26.9 | 26.7 | 26.3, 27.2 | 24.5 | 22.6, 26.4 | <0.05 | 0.955 | 0.857, 1.064 | |
| Current cigarette smoker | 20.6 | 20.2, 21.1 | 18.7 | 18.3, 19.1 | 30.8 | 28.8, 32.7 | <0.01 | 1.448* | 1.274, 1.647 | −10.25 |
| Binge drinker | 17.0 | 16.5, 17.4 | 14.8 | 14.4, 15.2 | 28.6 | 26.7, 30.6 | <0.01 | 1.390* | 1.245, 1.552 | −14.81 |
| Engaging in physical activity or exercise | 74.4 | 73.9, 74.8 | 73.7 | 73.3, 74.2 | 77.8 | 76.0, 79.5 | <0.01 | 1.048 | 0.936, 1.174 | |
| Ever being tested for human immunodeficiency virus | 42.1 | 41.4, 42.7 | 40.0 | 39.4, 40.6 | 50.9 | 48.7, 53.1 | <0.01 | 1.256* | 1.136, 1.388 | −5.10 |
| Having teeth cleaned in the past 12 months | 67.4 | 66.9, 68.0 | 69.7 | 69.2, 70.2 | 55.6 | 53.4, 57.8 | <0.01 | 0.626* | 0.567, 0.691 | 3.27 |
| Having a flu shot in the past 12 months | 35.1 | 34.6, 35.6 | 37.5 | 37.1, 38.0 | 22.4 | 20.6, 24.1 | <0.01 | 0.834* | 0.748, 0.931 | 6.41 |
| Ever having a mammogram | 64.8 | 64.1, 65.5 | 68.9 | 68.2, 69.5 | 37.2 | 34.2, 40.3 | <0.01 | 0.876 | 0.725, 1.057 | |
| Ever having a Papanicolaou test | 92.7 | 92.2, 93.1 | 93.2 | 92.7, 93.7 | 89.0 | 86.8, 91.1 | <0.01 | 1.015 | 0.795, 1.296 | |
| Ever having a prostate-specific antigen test | 60.8 | 59.8, 61.8 | 63.0 | 62.1, 63.9 | 41.1 | 36.2, 46.0 | <0.01 | 0.596* | 0.473, 0.752 | 3.46 |
| Ever having a sigmoidoscopy examination | 61.8 | 61.2, 62.5 | 62.9 | 62.3, 63.5 | 43.3 | 38.4, 48.3 | <0.01 | 0.622* | 0.502, 0.772 | 1.79 |

Abbreviation: CI, confidence interval.

* $P < 0.01$.

[a] Data were weighted to account for the sample design.

[b] Chi-squared test for the difference in prevalence point estimates between landline and cell phone survey data.

[c] Adjusted odds ratio for the cell phone survey versus the landline survey. In logistic regression models, results were adjusted for age, gender, education, marital status, and employment status.

[d] Weight (kg)/height $(m)^2$.

Because noncoverage bias is a product of the level of noncoverage and the degree to which respondents and nonrespondents differ, the approach of using a cell phone survey appears to have reduced the potential for noncoverage bias by addressing both issues—reducing the level of noncoverage and improving participation among respondents with characteristics different from those of the original pool of respondents. This is a problem which cannot be solved by the use of traditional weighting methods, which only adjust the proportionality of groups interviewed. If a significant and different subset of the population is excluded (such as seen here with young respondents), finding a means of interviewing and including these persons in the final results is the only viable mechanism for reducing the potential for bias.

Interviewing respondents by cell phone also appears much more costly than conducting landline telephone surveys. The financial costs associated with conducting cell-phone-only interviews are approximately 4–5 times those of conducting a similar interview via landline phones (6). However, more recent BRFSS experiences (unpublished data) show that the cost ratio is more like 3–4.

Sampling and interviewing respondents by cell phone is now a necessity if surveys conducted by telephone are to provide valid, reliable, and representative data. With the rapid growth in the size of the cell-phone-only population and its continued concentration among younger people, health surveillance systems which use telephone survey methods are facing a challenge in obtaining high-quality data from younger adults, because landline-based estimates of certain characteristics and behaviors are biased by the absence of the cell-phone-only population. On the basis of this study, we found that it is possible and necessary to conduct the BRFSS interview with respondents over a cell phone, although the participation rates are generally lower than they are for landline surveys and the costs per interview are higher. Such surveys, because of issues pertaining to differential nonresponse rates and costs per interview, should include all eligible sample members reached by telephone and not simply focus on cell-phone-only adults. For these reasons, beginning in 2009, the BRFSS expanded its traditional landline-based RDD survey to a dual-frame survey of landline and cell-phone-only numbers in all 50 states and the District of Columbia. In the future, adults in the cell phone sample who also have landline telephone service may additionally be interviewed.

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