



Practice of Epidemiology

Feasibility of Including Cellular Telephone Numbers in Random Digit Dialing for Epidemiologic Case-Control Studies

Lynda F. Voigt*, Stephen M. Schwartz, David R. Doody, Spencer C. Lee, and Christopher I. Li

* Correspondence to Dr. Lynda F. Voigt, Program in Epidemiology, Division of Public Health Sciences, Fred Hutchinson Cancer Research Center, 1100 Fairview Avenue North, P.O. Box 19024, Seattle, WA 98109 (e-mail: lvoigt@fhcrc.org).

Initially submitted May 19, 2010; accepted for publication August 24, 2010.

The usefulness of landline random digit dialing (RDD) in epidemiologic studies is threatened by the rapid increase in households with only cellular telephone service. This study assessed the feasibility of including cellular telephone numbers in RDD and differences between young adults with landline telephones and those with only cellular telephones. Between 2008 and 2009, a total of 9,023 cellular telephone numbers were called and 43.8% were successfully screened; 248 men and 249 women who resided in 3 Washington State counties, were 20–44 years of age, and used only cellular telephones were interviewed. They were compared with 332 men and 526 women with landline telephones interviewed as controls for 2 case-control studies conducted in parallel with cellular telephone interviewing. Cellular-only users were more likely to be college educated and less likely to have fathered/birthed a child than were their landline counterparts. Male cellular-only users were less likely to be obese and more likely to exercise, to be Hispanic, and to have lower incomes, while female cellular-only users were more likely to be single than landline respondents. Including cellular telephone numbers in RDD is feasible and should be incorporated into epidemiologic studies that rely on this method to ascertain subjects, although low screening rates could hamper the representativeness of such a sample.

bias (epidemiology); case-control studies; epidemiologic methods; selection bias; telephone

Abbreviation: RDD, random digit dialing.

Random digit dialing (RDD), an efficient method of creating an equal probability sample of all possible landline telephone numbers in a geographic area of interest, has been used to identify and recruit controls for epidemiologic case-control studies for more than 30 years. Landline RDD included almost all households as the percentage of households with landline telephones in the United States rose from 90% in the late 1970s to 97.6% by 2000 (1, 2). Cellular telephone numbers were traditionally excluded from RDD for surveys and epidemiologic studies for legal, ethical, and technical reasons (3, 4) and because, until recent years, almost all adults with cellular telephones could be reached on their household landline telephone. The proportion of US households without a landline telephone but with at least 1 member who had cellular telephone service increased from 2% in 2003 to 23% in early 2009 with variation by state and urbanicity (3, 5, 6). In 2009, 41% of adults less than 30 years

of age but only 5% of those 65 years or older resided in households with only cellular telephones (6). However, the percentage of adults with only cellular phones has increased steadily in all age groups since 2003 (6). Population-based surveys have found demographic, lifestyle, and health differences between adults in cellular-only households and those in landline households (3, 6–8). Standard survey-weighting techniques and adjustment have been insufficient to remove bias from telephone surveys that exclude cellular phones (7, 9–11).

Case-control studies that identify controls by using landline RDD exclude cases without landline phones to maintain comparability (12). Two current case-control studies of cancer conducted by 2 of us (S. M. S., C. I. L.) found that the percentage of cases aged 20–29 years excluded from analyses because they had only cellular telephone service has increased from less than 4% prior to 2005 to 17%–24% in

recent years (unpublished data). The increasing proportion of cases and potential controls that are excluded in studies using landline RDD brings into question the generalizability of the results and impacts statistical power, particularly in studies that include large numbers of young adults.

Cellular telephone numbers have not yet been included in RDD for epidemiologic case-control studies to our knowledge. We undertook this study to assess the feasibility of conducting RDD for epidemiologic studies using cellular telephone numbers, to compare the process of landline and cellular RDD, and to explore differences between men and women 20–44 years of age with landline phones and those with only cellular phones.

MATERIALS AND METHODS

To address our aims, we sought 1) to identify a sample of 250 men and 250 women 20–44 years of age who used only cellular telephones and were residents of King, Pierce, or Snohomish County, Washington State, between October 2008 and January 2009 and 2) to compare characteristics of these individuals with those of similarly aged men and women ascertained as controls through traditional landline RDD in case-control studies of breast cancer and testicular cancer conducted concurrently in the same population. All procedures and data collection instruments for the cell phone study and the 2 case-control studies were approved by the Fred Hutchinson Cancer Research Center Institutional Review Board.

Identification of cell phone-only users

To identify the sample of cellular-only users, we first identified all of the thousand blocks (area code, prefix, next digit) that were coded as cellular and originally assigned in King, Pierce, and Snohomish counties in Washington State using the April 2008 NPA-NXX Active Code List—Thousands Block (referred to as “NNACL-TB”) file purchased from Telcordia (Piscataway, New Jersey). From these, we randomly selected thousand blocks with replacement and added a 3-digit random number to create a telephone number. We selected a total of 9,000 unique telephone numbers this way. We called each number between October 1, 2008, and January 31, 2009. We identified an additional 23 telephone numbers that were cellular during our landline RDD for controls for the 2 case-control studies during the same time period and attempted to screen each of these for eligibility for the cell phone study.

The first call to all cellular telephone numbers was made on a weekend when many subscribers have free minutes and would not be charged for our call. If the number was answered, the first 2 questions after a short introduction were “Are you driving a car now?” and “Are you in a safe place to talk?” (refer to supplementary material posted on the *Journal*’s website (<http://aje.oxfordjournals.org/>)). The interviewer told the respondent that he/she would call back later and immediately terminated the call if either the first question was answered “yes” or the second “no.” We assumed that the person who answered the cellular phone was

the primary user and screened him or her for the following eligibility criteria: 1) between 20 and 44 years of age; 2) current resident of King, Pierce, or Snohomish County; and 3) no landline telephone or never answered his/her landline telephone. We included respondents who had a landline telephone but never answered it because these individuals are not accessible by landline RDD. A respondent reached at a cellular phone that was primarily used for business was included if he or she also used the cell phone for personal calls. If the respondent was eligible, he or she was asked to complete a 10–15 minute gender-specific interview that included questions related to demographic and lifestyle factors, reproductive history, mammography history, and characteristics of cell phone use (refer to supplementary material). Participants were given \$20 for completion of the questionnaire. If the respondent was willing to complete the interview at a later time, we offered to call back and also gave the website addresses (cellphonestudy.org, cellphonestudy.com, and cellphonestudy.net) where the respondent could complete the questionnaire online.

We allowed the phone to ring at least 9 times on each of the first 2 calls and at least 6 times on subsequent calls. A maximum of 8 calls were made at different times and days of the week over 2–4 weeks. The interviewer left up to 2 messages if the number was answered with a recording. The message briefly explained the study, stated that the interviewer would be calling back, and left the study website address.

Numbers that were never answered by a person and appeared to be working cell phone numbers were recontacted 2 months later. All respondents who refused except those who were hostile to our call and those who asked to be “removed from our list” ($n = 607$) were also recontacted 2 months later. A maximum of 8 additional calls were made during the recontact process.

Comparison of cell phone-only and landline users

We compared information from the cell-only respondents with information collected during in-person interviews of 526 female and 332 male controls recruited using landline RDD for ongoing case-control studies of breast cancer in young women and testicular cancer in young men conducted by 2 of us (C. I. L. for breast cancer, S. M. S. for testicular cancer). Landline (including voice over Internet protocol (VoIP)) thousand blocks were randomly selected from the Telcordia files as described above. Both studies used Mitofsky-Waksberg RDD with a clustering factor (“ k ”) of 5 to identify potential controls and to screen for study eligibility (13). Eligible and willing respondents were sent a letter with more information about the study. In-person structured interviews were administered by trained interviewers at the respondent’s home or another place of their choosing. Controls were frequency matched to the age distribution of the cases. Male controls were offered \$50 for completing the interview, and female controls were offered \$20. From these 2 studies, we included only controls with reference years 2005–2007 because interviewing was nearly complete for these reference years. Reference dates were assigned to controls to approximate the age-specific

distribution of case diagnosis dates, and all interview questions referred to the time period prior to each control's reference date. As of November 2009, 60% and 48% of the screened and eligible breast cancer controls and testicular cancer controls, respectively, identified through landline RDD for these reference years had been interviewed; 25% and 46%, respectively, had refused to participate in the corresponding case-control study, and 15% and 6% had not yet been interviewed. One woman with a prior diagnosis of breast cancer and one woman with no information about prior breast cancer were excluded from the cell phone study participants, because such women were not eligible to be breast cancer study controls.

Analytical methods

For descriptive comparisons of characteristics, we adjusted the distribution of the cell phone group to the age distribution of the landline group using the method of direct standardization so that differences in Tables 3 and 4 are not attributable to age. We used odds ratios and 95% confidence intervals as a measure of association, computing them using logistic regression with cell/landline status as the dependent variable and adjusting for age and other confounding variables (Stata, version 10.1, software; StataCorp LP, College Station, Texas). We assessed possible confounding by Hispanic origin, marital status (women), education, income, and obesity (<30 vs. \geq 30 kg/m²) and included in the model those that changed the odds ratios by more than 15%.

RESULTS

Of all working or possibly working cellular telephone numbers, 43.8% were successfully screened (Table 1). In comparison, 75.1% of presumed residential landline telephone numbers were successfully screened. Respondents at 36% of the screened cellular numbers reported that they did not have a landline phone; 61% of those screened who had both a landline and a cell phone received most of their calls on their cell phones, and 14% of those screened reported that they never answered their landline telephone. A total of 77.5% of eligible cellular respondents completed the interview, 7.5% of respondents completed the screening online, and more than a third of eligible respondents completed the questionnaire online. All eligible respondents who completed the screening online also completed the questionnaire.

Table 2 shows patterns of cell phone use among interviewed men and women who used only cell phones. About 10% of respondents had a landline telephone but never answered it; 18% of each sex reported using other cell phones regularly, whereas only about 5% reported that the cellular telephone that was called was shared with other adults 20–44 years of age at least one third of the time. About a third of the respondents had more than 1,000 minutes included in their cell phone plan. Most respondents had cellular service contracts as opposed to prepaid cellular service. Almost all respondents reported that their cell phone was on more than

12 hours a day. A majority of respondents reported they would be very or somewhat willing to participate in a study requiring a 90-minute in-person interview. Respondents reported that they preferred to be called for research studies on their cell phones on weekdays between 5 and 9 PM (data not shown). The preferred time for weekend calls was afternoon, although 30% did not want to be called on weekends at all. Characteristics of cellular telephone usage were similar when stratified by sex, race, and interview mode (telephone or self-administered online).

After adjustment for age, women with only cell phones were more likely to be single, more likely to have a college education, and less likely to have birthed a child than women with landlines (Table 3). The 2 groups were otherwise similar. Men with only cell phones were more likely to be Hispanic and to have a college education. They were less likely to be obese, to have a household income >\$50,000, and to have fathered a child, and they more frequently engaged in physical activity 5–10 hours a week or more than 10 hours a week as an adult and 15 or more hours a week as an adolescent than did their landline counterparts (Table 4). No differences were seen for race, alcohol use, and prior infertility testing.

Female Hispanic cell phone respondents were much more likely to complete the interview by telephone than on the website. Odds ratios for all other variables among women were similar when stratified by interview mode. All Hispanic male cell phone respondents completed the interview by phone. Odds ratios stratified by interview mode in men were similar for all other variables except education and exercise. Male cell-only Web responders were more likely to have a college degree and exercised more as adolescents and adults than did landline respondents, whereas cell respondents interviewed by phone were similar to their landline counterparts (data not shown).

DISCUSSION

This study demonstrates the feasibility of cell phone RDD and confirms the need for including cell phones in RDD in order to obtain a representative population-based control group for epidemiologic case-control studies.

Our study was limited by the small number of women less than 30 years of age in the landline comparison sample, and adjustment by 5-year age group may have been insufficient to control confounding. Another limitation is that we combined data that were collected by telephone interview and self-administered Web interviews for the cell-only users, whereas the data for the landline users were collected via in-person interviews. These diverse sources may not provide comparable data, and this could account for the differences we found between cell users and landline users (14, 15). Some respondents may have considered the questions related to reproductive history to be sensitive. Studies have found that sensitive information and questions related to social desirability are reported more accurately on self-administered questionnaires than by telephone or in-person interviews (14–16). A case-control study that compared health and residential history data collected on self-administered

Table 1. Response Outcomes in Cell Phone and Landline Random Digit Dialing, Seattle-Puget Sound Region, Washington State, 2008–2009

	Cellular Telephone Numbers Called			Landline Telephone Numbers Called ^a		
	Total Cellular Numbers (n = 9,023)	% of Total	% of Working/ Presumed Working Numbers	Total Landline Numbers (n = 46,105)	% of Total	% of Residential/ Presumed Residential Numbers
Not assigned/disconnected	1,120	12.4		23,744	51.5	
Not a household or business				499	1.1	
Data line				2,085	4.5	
Total not assigned or disconnected	1,120	12.4		26,328	57.1	
Unknown if working, unscreened						
Automated recording	205	2.3	2.6			
Never answered	61	0.7	0.8	2,085	4.5	
Always busy	46	0.5	0.6	937	2.0	
Screened, business only						
Ineligible, business only	327	3.6	4.1	5,998	13.0	
Unscreened						
Voice mail, all attempts	1,580	17.5	20.0	1,092	2.4	10.2
Refused screening	2,550	28.3	32.3	1,590	3.4	14.8
Screened						
Ineligible	2,493	27.6	31.5	7,208	15.6	67.0
Eligible	641	7.1	8.1	867	1.9	8.1
Refused survey	144	1.6				
Completed survey	497	5.5				
Total screened	3,461	38.4	43.8	8,075	17.5	75.1
Total cellular working or presumed working	7,903					
Total landline residential or presumed residential				10,757		
Screening percentage		43.8 ^b			75.1 ^c	
Interview percentage		77.5 ^d			— ^e	
Screening mode						
Telephone interviewer	3,201	92.5		8,075		100.0
Website (self-administered)	260	7.5		0		
Interview mode						
Telephone interviewer	316	63.6		0		
Website (self-administered)	181	36.4		0		
In person	0			858		100.0

^a Landline random digit dialing for breast and testicular cancer case-control studies from February 20, 2008, through February 5, 2010.

^b Number of cellular telephone numbers screened divided by total number of working and presumed working numbers multiplied by 100.

^c Number of landline telephone numbers screened divided by total number of presumed residential numbers (voice mail, refused screening, ineligible, eligible) multiplied by 100. The landline response percentage is 71.2% if business numbers are considered screened and “unknown if working, unscreened” are included in the denominator.

^d Number interviewed divided by number eligible (497/641).

^e —, interviewing is still in progress.

Web questionnaires with telephone interviews found Web questionnaires to be more reliable but found no differences between survey mode and participant characteristics for cases compared with controls (17). We found differences by interview mode for the cell responders only for Hispanic origin, education, and exercise.

An additional limitation of this study is that information from cell phone participants reflected their status in 2008

and 2009, whereas the information from landline participants referred to their status prior to reference dates that ranged from 2005 to 2007. We believe that any changes in the characteristics of interest over this time period in adults aged 20–44 years would have been too small to produce the differences that we observed.

We found differences between the Seattle-Puget Sound area cell only and landline respondents with respect to

Table 2. Patterns of Cell Phone Use by Interviewed Men and Women, Cell Phone Random Digit Dialing Study, Seattle-Puget Sound Region, Washington State, 2008–2009

	%	
	Men (n = 248)	Women (n = 249)
Have landline telephone but never answer	14	9
This cell phone is		
A prepaid cell phone	13	11
Shared with one or more other adults ^a	4	6
On >12 hours/day	94	96
Respondent uses another cell phone regularly	18	18
Included cell phone plan minutes		
<500	20	18
500–1,000	35	35
>1,000	34	28
Unsure	11	19
Very or somewhat willing to complete a 90-minute in-person interview	68	75

^a Shared with at least one adult 20–44 years of age at least one third of the time.

Hispanic ethnicity, education, marital status, ever having birthed/fathered a child, obesity, and exercise. We compare our results with those from 3 population-based surveys conducted between 2005 and 2009 that collected demographic and health-related information on cell-only and landline households (3, 6, 7). All 3 surveys included adults of any age and did not separate results by age and gender, which limits the comparison of results with those from our study. Only one study adjusted for sex, race, and age (3). Our findings agree with some, but not all, of the results of these surveys (Table 5). Our study and 2 of the surveys found that cell phone-only users were less likely than landline users to have ever had a child or to be currently living with children (3, 7). Our study and one survey found that cell-only users were less likely to be married than were landline users (3). The differences in both variables persisted in our data when stratified by 5-year age group (data not shown). Although there are some consistencies across studies that have compared cellular-only users with landline users, there are also several differences. These differences in demographic and lifestyle characteristics may be due to geographic variations in the distributions of these characteristics across different regions of the United States, as well as to local differences in those who are or who are not cellular-only users. Thus, the impact of choosing to include or not to include a cell phone sample for a given regional study is likely to vary on the basis of the exposures and diseases of interest, as well as on the respondent's age.

Identifying and recruiting potential controls who use cellular but not landline telephones are feasible: 96% of the cell-only respondents in our study reported that their cell

phones were on more than 12 hours a day, so they are accessible by cell phone. This is consistent with the 2005 finding by Tuckel and O'Neill (8) that 94% of people with only cell phones kept them on always or most of the time. Screened individuals in our study were willing to complete brief interviews on their cellular phones or online, and more than two thirds of the men and three fourths of the women answered that they would be very or somewhat willing to complete a 90-minute in-person interview. Most of the 260 (7.5%) respondents who completed the screening online used the website information left on their voice mail and never spoke to an interviewer. We believe that the option of completing the interview online may have contributed to a higher interview response, because 37% of the interviews were completed online. A Census Bureau survey conducted in 2008 found that nearly half of cell-only households reported a preference for completing information forms online (18). The option of self-administrated online screening and interviewing needs further exploration. Recontact of numbers that were unanswered or resulted in refusal during the initial series of calls improved response proportions; 17% of the 5,079 numbers that we recontacted were successfully screened.

An important consideration with respect to implementation of cellular telephone-based RDD is response proportions. The screening response that we experienced with cellular RDD is much lower than the ~75% screening response that we achieved for landline RDD during a similar time period but similar to the highest response (47.5%) from recent surveys targeting cell phones in other areas of the United States (7). The lower screening proportion for cell phone RDD was driven by the relatively high proportions of screening refusals and "voice mail" on all attempts. We suspect that some of the cell phones that were always answered by voice mail belonged to people who primarily use landline telephones and thus would have been ineligible for our study. This suspicion is supported by data from a study that found a higher proportion of cell-only users kept their cell phones on all of the time than respondents with both cell and landline telephones (8). Nevertheless, the low screening response proportions achieved can jeopardize the validity of a case-control study that uses this method.

Another important limitation of cell phone RDD is that individuals may and often do retain a cell phone number when moving into or out of a study's geographic area, with 10% of the cellular numbers screened in our study belonging to individuals who resided outside the 3-county area, but we have no way of measuring how many people resided in our 3-county area but had a cellular number assigned to another geographic area and were not in our sampling frame. One solution is to eliminate cell-only cases with cellular numbers assigned in another geographic area to achieve comparability with controls. However, sample size and representativeness of the sample may be compromised if the number of cases excluded for this reason increases.

A more difficult challenge is to integrate landline and cellular telephone samples appropriately because landline telephones are associated with households, whereas cellular telephone numbers are primarily associated with individuals

Table 3. Characteristics of Young Women Having Landline Telephones Compared With Those Having Only Cellular Telephones, Seattle-Puget Sound Region, Washington State, 2008–2009 (Cell Phone Participants) and 2005–2007 (Landline Participants)

Characteristic	Landline (n = 526)		Cellular Only (n = 247)		OR ^a	95% CI
	No.	%	No.	% ^b		
Age, years						
20–24	3	0.6	77	31.2		
25–29	8	1.5	61	24.7		
30–34	50	9.5	48	19.4		
35–39	155	29.5	32	13.0		
40–44	310	58.9	29	11.7		
Nonwhite	76	14.7	59	22.8	1.39	0.80, 2.41
Hispanic origin ^c	24	4.6	19	12.8	1.57	0.65, 3.78
Current smoker	67	12.8	40	12.9	1.14	0.63, 2.06
Ever used oral contraceptives ^c	480	91.3	196	91.6	1.10	0.56, 2.18
Ever used birth control shots	67	12.7	49	17.4	1.19	0.68, 2.06
Obese (body mass index ≥ 30)	101	19.2	35	18.3	0.93	0.54, 1.61
College degree ^e	305	58.2	148	67.3	1.92	1.19, 3.11
Ever had a live- or stillbirth ^d	480	93.2	47	55.0	0.07	0.04, 0.12
Ever had a mammogram ^e	246	79.6	22	75.9	0.80	0.33, 1.97
First-degree family history of breast cancer	47	8.9	14	13.0	1.28	0.60, 2.72
Among women aged ≥ 35 years	43	9.3	7	13.3	1.43	0.61, 3.39
Second-degree family history of breast cancer	132	25.1	61	21.4	0.98	0.61, 1.58
Among women aged ≥ 35 years	117	25.2	12	20.3	0.74	0.38, 1.45
Marital status						
Married	407	77.7	73	39.2	1.0	Referent
Single	83	15.8	142	54.5	7.20	4.41, 11.75
Living with partner	34	6.5	31	6.3	1.82	0.82, 4.01
Household income, US dollars ^f						
<25,000	40	7.6	49	9.9	1.0	Referent
25,000–<50,000	66	12.6	73	26.5	1.67	0.75, 3.71
$\geq 50,000$	417	79.7	109	63.6	1.16	0.53, 2.53

Abbreviations: CI, confidence interval; OR, odds ratio.

^a Odds ratio comparing women having cell phones only with women having landline telephones, adjusted for age (20–29, 30–34, 35–39, 40–44 years).

^b Adjusted to age distribution of landline group by using direct standardization.

^c Odds ratios also adjusted for marital status (married, single, living with partner).

^d Among women aged 30–44 years.

^e Among women aged 40–44 years.

^f Odds ratios also adjusted for marital status (married, single, living with partner) and education (no college degree, college degree).

(4). One possibility is to screen cellular telephone numbers the same way landline numbers are screened by enumerating all members of the respondent's household and randomly selecting one person from all who are eligible (4, 19). Landline RDD reduces the probability of inclusion by one half when 2 telephone numbers ring in the same household. A similar reduction will need to account for cell phone sharing and multiple cell phones among eligible respondents within a single household. We found that 5%

of cell-only users share their cell phone one third of the time or more with at least one other adult who is 20–44 years of age, but we did not ascertain whether or not the adult sharing the cell phone lived in the same household or lived in a household with a landline telephone. A 2007 study found that 10%–20% of cell-only adults reported sharing their cell phone with another adult of any age at least one third of the time, with variation by geographic area (7).

Table 4. Characteristics of Young Men Having Landline Telephones Compared With Those Having Only Cellular Telephones, Seattle-Puget Sound Region, Washington State, 2008–2009 (Cell Phone Participants) and 2005–2007 (Landline Participants)

Characteristic	Landline (n = 332)		Cellular Only (n = 248)		OR ^a	95% CI
	No.	%	No.	% ^b		
Age, years						
20–24	45	13.6	57	23.0		
25–29	45	13.6	48	19.4		
30–34	107	32.2	63	25.4		
35–39	76	22.9	44	17.7		
40–44	59	17.8	36	14.5		
Nonwhite	72	21.8	63	19.7	0.87	0.57, 1.32
Hispanic origin	11	3.3	18	7.3	2.25	1.03, 4.91
Current smoker ^c	55	16.6	52	20.4	1.50	0.96, 2.35
Ever fathered a child	197	59.5	80	37.9	0.35	0.24, 0.52
Obese (body mass index ≥ 30)	87	26.2	34	15.8	0.49	0.32, 0.77
Drank >14 alcoholic drinks/week	39	11.7	27	9.7	0.83	0.49, 1.42
Self or partner ever had infertility tests	21	6.7	12	6.1	0.94	0.45, 1.97
College degree	158	47.6	129	60.6	1.54	1.08, 2.20
Vigorous activity in grades 7–12, hours/week						
<6	99	29.8	49	20.7	1.00	Referent
6–<10	59	17.8	40	17.9	1.40	0.82, 2.39
10–<15	91	27.4	63	27.3	1.47	0.91, 2.37
≥ 15	83	25.0	80	34.1	2.00	1.25, 3.19
Vigorous activity in past 2 years, hours/week						
<2	110	33.1	47	22.0	1.00	Referent
2–<5	108	32.5	62	26.4	1.30	0.81, 2.08
5–<10	80	24.1	64	27.3	1.80	1.11, 2.91
≥ 10	34	10.2	63	24.5	3.87	2.24, 6.70
Household income, US dollars ^c						
<25,000	28	8.5	33	11.7	1.00	Referent
25,000–<50,000	67	20.4	70	27.8	0.92	0.49, 1.74
$\geq 50,000$	234	71.1	132	60.6	0.51	0.28, 0.93

Abbreviations: CI, confidence interval; OR, odds ratio.

^a Odds ratio comparing men having only cell phones with men having landline telephones, adjusted for age (20–24, 25–29, 30–34, 35–39, 40–44 years).

^b Adjusted to age distribution of landline group by using direct standardization.

^c Odds ratio also adjusted for college degree (no, yes).

A dual frame of landline and cell phone RDD with landline/cell-only status of cases as one of the frequency matching variables could be explored. Matched or stratified analyses by cellular status should be considered, particularly if the primary data collection is done by telephone, because differences of interview data have been found between landline and cellular telephone interviews (7). Stratification will also facilitate evaluation of the impact of different screening proportions between landline and cellular RDD.

Landline RDD alone can no longer produce a representative sample of the young adult US population and must be supplemented with cellular RDD (1, 7). Using landline RDD to recruit controls 45–64 years of age and 65 years

of age or older currently would exclude far fewer controls: 13% and 5% of the population, respectively (6). However, these percentages continue to rise (6). Methods to increase RDD screening response, such as refusal recontact and a monetary “thank you” to respondents, should be considered. The impact of nonresponse bias could substantially hamper scientific inferences if cellular RDD screening response proportions cannot be improved and if nonrespondents cannot be characterized. Further research is needed into methodological solutions for increasing cellular screening response, combining data from landline and cellular RDD, and accounting for geography, shared cellular telephones, and multiple cell phone households.

Table 5. Comparison of Current Study (Seattle-Puget Sound Region, Washington State, 2005–2009) Results With Results From 3 Population-based Surveys (Entire United States, 2005 and 2009; and Georgia, New Mexico, and Pennsylvania, 2007)

	Current Study, Men		Current Study, Women		NHIS, 2005 ^a		NHIS, 2009 ^b		BRFSS, 2007 ^c	
	% cell only/ % landline ^{e,f}	Adjusted OR	% cell only/ % landline ^{e,f}	Adjusted OR	% cell only/ % landline ^e	Adjusted OR	% cell only/ % landline ^e	Adjusted OR	% cell only/ % landline ^e	Adjusted OR
Sampling type	Landline: 2-stage RDD (2) Cell: single-stage RDD (2)		Landline: 2-stage RDD (2) Cell: single-stage RDD (2)		Household area sample ^d		Household area sample ^d		Landline: bank list-assisted RDD (2) Cell: systematic random sample	
Sampling area	Western Washington State		Western Washington State		Entire United States		Entire United States		Georgia, New Mexico, Pennsylvania	
Interview type	Landline: in person Cell: telephone or Web		Landline: in person Cell: telephone or Web		In person		In person		Telephone	
No. of respondents/ households	332 landline 248 cell only		526 landline 247 cell only		34,309 landline households 3,023 cell only households		9,373 landline households 2,826 cell only households		6,380 landline 572 cell only	
Respondent's age	20–44 years		20–44 years		≥18 years		≥18 years		≥18 years	
Hispanic origin	7.3/3.3	2.25*	12.8/4.6	1.57	17.3/12.1				21.4/13.9	
Nonwhite race	19.7/21.8	0.87	22.8/14.7	1.39	34.6/28.7 ^g				25.0/12.3 ^g	
Current smoking	20.4/16.6	1.50	12.9/12.8	1.14	33.3/19.4	1.49*	28.4/17.9		31.1/20.2	
Obesity	15.8/26.2	0.49	18.3/19.2	0.93	23.8/25.5	1.02	26.8/28.0		24.4/26.6	
Exercise	24.5/10.2	3.87* ^h			36.4/29.9	1.26 ⁱ	37.2/34.6 ⁱ			
Alcohol use	9.7/11.7	0.83 ^j			38.2/17.9	1.81* ^k	35.3/19.3 ^k		28.7/17.5 ^l	
Income	60.6/71.1	0.51 ^m	63.6/79.7	1.16 ^m	84.1/90.0 ⁿ					
College degree	60.6/47.6	1.54*	67.3/58.2	1.92*	20.6/26.5					
Married			39.2/77.7	0.19*	33.2/60.7				32.0/62.8	
Children	37.9/59.5	0.35* ^o	55.0/93.2	0.07* ^p	33.1/39.1 ^q				39.5/36.6 ^q	

Abbreviations: BRFSS, Behavioral Risk Factor Surveillance System; NHIS, National Health Interview Survey; OR, odds ratio; RDD, random digit dialing.

* $P < 0.05$.^a National Health Interview Survey (3).^b National Health Interview Survey (6).^c Behavioral Risk Factor Surveillance System (7).^d www.cdc.gov/nchs/nhis/about_nhis.htm#sample_design.^e Percentage of those with characteristic among cell-only respondents/percentage of those with characteristic among landline respondents.^f Percentages adjusted for age.^g Non-Hispanic, nonwhite.^h Current, ≥10 hours/week.ⁱ Current regular leisure activity.^j More than 14 drinks/week.^k Five or more drinks/day at least once in the past year.^l Binge drinking in the last 30 days.^m More than 50,000 dollars/year.ⁿ Above poverty level.^o Ever fathered a child.^p Ever birthed a child among women 30–44 years of age.^q Children currently living in household.

ACKNOWLEDGMENTS

Author affiliations: Program in Epidemiology, Division of Public Health Sciences, Fred Hutchinson Cancer Research Center, Seattle, Washington (Lynda F. Voigt, Stephen M. Schwartz, David R. Doody, Spencer C. Lee, Christopher I. Li); and Department of Epidemiology, School of Public Health and Community Medicine, University of Washington, Seattle, Washington (Lynda F. Voigt, Stephen M. Schwartz, Christopher I. Li).

This work was supported by the National Cancer Institute (grants 5R01CA129621-02, R01CA105041, R01CA085914).

The authors wish to thank Nancy Blythe and the Hutchinson Collaborative Data Services shared resource for their valuable assistance with the conduct of this study.

Conflict of interest: none declared.

REFERENCES

- Lavrakas PJ, Shuttles CD, Steeh C, et al. The state of surveying cell phone numbers in the United States: 2007 and beyond. *Public Opin Q.* 2007;71(5):840–854.
- Voigt LF. Use of random digit dialing to recruit representative population samples. In: Roberts AR, Yeager K, eds. *Evidence-Based Practice Manual: Research and Outcome Measures in Health and Human Services*. New York, NY: Oxford University Press; 2004:410–419.
- Blumberg SJ, Luke JV, Cynamon ML, et al. Recent trends in household telephone coverage in the United States. In: Lepkowski JM, Tucker C, Brick JM, et al, eds. *Advances in Telephone Survey Methodology*. New York, NY: John Wiley & Sons, Inc; 2008:56–86.
- Frankel MR, Battaglia MP, Link M, et al. Integrating cell phone numbers into random digit-dialed (RDD) landline surveys. In: Proceedings of the Section on Survey Research Methods, Salt Lake City, UT, July 29–August 2, 2007. Alexandria, VA: American Statistical Association; 2007. (<http://www.amstat.org/Sections/Srms/Proceedings/>).
- Blumberg SJ, Luke JV. Wireless substitution: state-level estimates from the National Health Interview Survey, January–December, 2007. Hyattsville, MD: National Center for Health Statistics; 2009. (<http://www.cdc.gov/nchs/data/nhsr/nhsr014.pdf>).
- Blumberg SJ, Luke JV. Wireless substitution: early release of estimates from the National Health Interview Survey, January–June, 2009. Hyattsville, MD: National Center for Health Statistics; 2009. (<http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless200912.htm>).
- Link MW, Battaglia MP, Frankel MR, et al. Reaching the US cell phone generation. *Public Opin Q.* 2007;71(5):814–839.
- Tuckel P, O'Neill H. Ownership and usage patterns of cell phones: 2000–2005. Presented at the Second International Conference on Telephone Survey Methodology, Miami, FL, January 11–15, 2006.
- Blumberg SJ, Luke JV. Reevaluating the need for concern regarding noncoverage bias in landline surveys. *Am J Public Health.* 2009;99(10):1806–1810.
- Delnevo CD, Gundersen DA, Hagman BT. Declining estimated prevalence of alcohol drinking and smoking among young adults nationally: artifacts of sample undercoverage? *Am J Epidemiol.* 2008;167(1):15–19.
- Blumberg SJ, Luke JV. Coverage bias in traditional surveys of low-income and young adults. *Public Opin Q.* 2007;71(5):734–749.
- Potthoff RF, Halabi S, Schildkraut JM, et al. Flexible frames and control sampling in case-control studies: weighters (survey statisticians) versus anti-weighters (epidemiologists). *Am Stat.* 2008;62(4):307–313.
- Waksberg J. Sampling methods for random digit dialing. *J Am Stat Assoc.* 1978;73:40–46.
- Dillman DA. Mixed-mode surveys. In: Dillman DA, ed. *Mail and Internet Surveys, The Tailored Design Method, Second Edition*. Hoboken, NJ: John Wiley & Sons, Inc; 2007:217–244.
- Groves RM, Fowler FJ, Couper MP, et al. Methods of data collection. In: Groves RM, Fowler FJ, Couper MP, et al, eds. *Survey Methodology*. Hoboken, NJ: John Wiley & Sons, Inc; 2004:155–160.
- Kreuter F, Presser S, Tourangeau R. Social desirability bias in CATI, IVR and Web surveys. *Public Opin Q.* 2008;72(5):847–865.
- Rankin KM, Rauscher GH, McCarthy B, et al. Comparing the reliability of responses to telephone-administered versus self-administered Web-based surveys in a case-control study of adult malignant brain cancer. *Cancer Epidemiol Biomarkers Prev.* 2008;17(10):2639–2646.
- Bates N. Cell-only households: a good target for Internet surveys? [electronic article]. In: *Survey Practice*. Deerfield, IL: American Association for Public Opinion Research; 2009. (<http://surveypractice.org/2009/10/17/cell-internet-surveys/>).
- Brick JM, Edwards WS, Lee S. Sampling telephone numbers and adults, interview length, and weighting in the California Health Interview Survey Cell Phone Pilot Study. *Public Opin Q.* 2007;71(5):793–813.