

Are Shoppers Representative of the Population? Using Geofenced Grocery, Convenience, and Home Improvement Stores to Represent the Population

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Abstract

General population surveys traditionally sample people from households because people are easiest to locate where they live. However, advances in mobile phone and geolocation technologies have made it simple to locate people in other places. For example, most people visit a grocery or convenience store to purchase food and household items at least once a week. Combining these stores with home improvement stores should produce a convenience sampling frame that captures most of the general population, and perhaps some people who are not attached to a household. If so, can such a frame produce health estimates comparable to those obtained from traditional probability samples? This paper presents results from a national survey of geofenced grocery, convenience, and home improvement stores that are part of MFour's Surveys-on-the-Go® mobile panel. We sampled 1,000 mobile panel members when they crossed a geofenced set 50 meters from the entrance to each store. Sampled panel members were eligible to participate even if they were not shopping at that store, but could only participate once in the study, even if they crossed additional geofences. The questionnaire, which was completed through an app on the respondent's smart phone, included health measures taken from the Behavioral Risk Factor Surveillance System (BRFSS) core questionnaire so we can benchmark results to a high-profile and respected probability sample survey. The questionnaire also asked respondents to take a picture of an alcohol, tobacco, or sugar-sweetened beverage display to demonstrate innovative data collection not available, or not often used in traditional household surveys.

Key Words: nonprobability sampling, geofencing, health surveys, benchmarking

1. Background & Research Questions

1.1 The case for geofenced sampling (and other nonprobability methods)

As traditional probability sample surveys become more expensive (prohibitively expensive for some funders), survey methodologists must seek new sampling and data collection methods that are less expensive but still maintain representation for key demographics and outcomes. Geofenced samples are a promising potential replacement, particularly for surveys that sample geographically by design.

Geofencing is the process of drawing a virtual barrier around a specific geolocation (i.e., latitude/longitude). Surveys using this method, usually panel surveys, either provide

panel members with a device that tracks their location, or rely on panel members' smart phones to provide that information. Geofences are typically drawn around purposive sampling points, such as the entrance to a store or doctor's office, or location of an advertisement, but the approach can be used with any geographic location. Figure 2 provides a visual representation of hypothetical geofences in the U.S. state of Tennessee for two different types of locations (e.g., two different store chains).

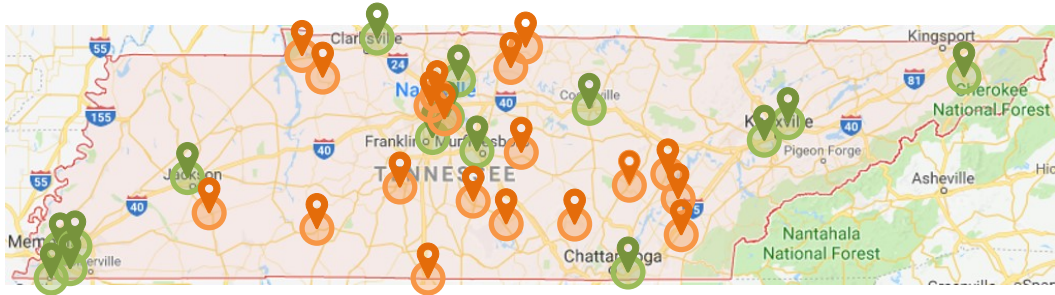


Figure 2: Hypothetical representation of two geofenced store chains in the U.S. state of Tennessee (Geofences are not presented to scale.)

Geofencing essentially provides a more systematic way to conduct so-called “intercept” sampling. As a replacement for traditional general population probability samples, which usually sample people at home, a major strength of this method is that potential respondents can be reached in places other than their home. While people are increasingly difficult to contact by phone or at home, they are also increasingly interacting with their mobile devices, providing a new way to intercept their attention and recruit them into a survey. Even if a survey's goal is not to sample specific doctors' offices or store chains, being able to sample people in contexts they encounter in their day-to-day lives provides another way to obtain a general population, and potentially representative, sample.

While progress has been made in understanding the potential uses and limitations of nonprobability samples in general, (e.g., Dutwin & Buskirk, 2017) there is little if any research on geofenced data collection.

1.3 Research questions

Question #1: Can a geofenced sample of grocery, convenience, and home improvement stores produce demographic and health estimates similar to a gold-standard probability sample health survey?

Question #2: Which estimates are comparable to that gold standard and which are not?

Question #3: When estimates differ, do they tend to over- or underestimate, and at what magnitude?

2. Methods

2.1 Target population and data collection approach for the current study

The target population for this study was noninstitutionalized adults age 18 and older living in the United States. This target population was chosen because the overall study goal is to benchmark geofenced survey estimates with estimates from the Behavioral Risk Factor Surveillance System (BRFSS).

MFour's *Surveys on the Go*[®] mobile opt-in panel was used as the geofenced data source because of its large size (approximately two million users) and general representativeness. This panel is single-source (i.e., not combined with other Web or smartphone panels), which limits overlap with other online opt-in panels. Recruitment is done by word-of-mouth only, and efforts are taken to avoid so-called "professional respondents." Compared to the U.S. population, the MFour panels skews younger and more single. On other demographics, such as sex, race/ethnicity, and education, the MFour panel and general population distributions are relatively similar (see Figure 2).

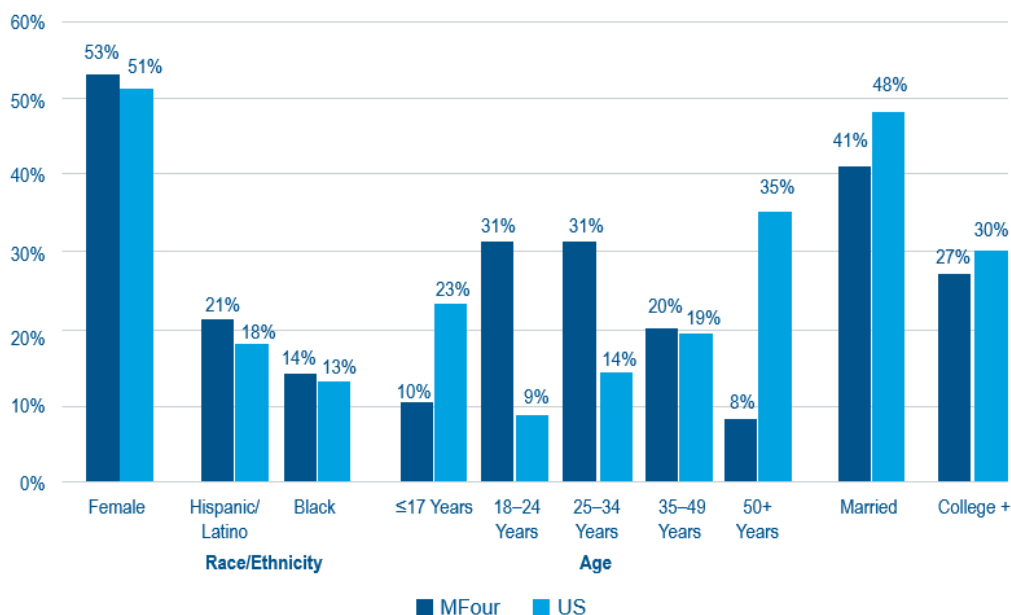


Figure 2: MFour panel vs. U.S. general population on key demographics

Members must have a smart phone and allow the *Surveys on the Go*[®] app to access location services in order to be part of the panel. MFour then sends survey invitations when panel members trip predefined geofences. Figure 3a shows the app dashboard on which a panel member sees all available surveys, and 3b shows an example question screen.

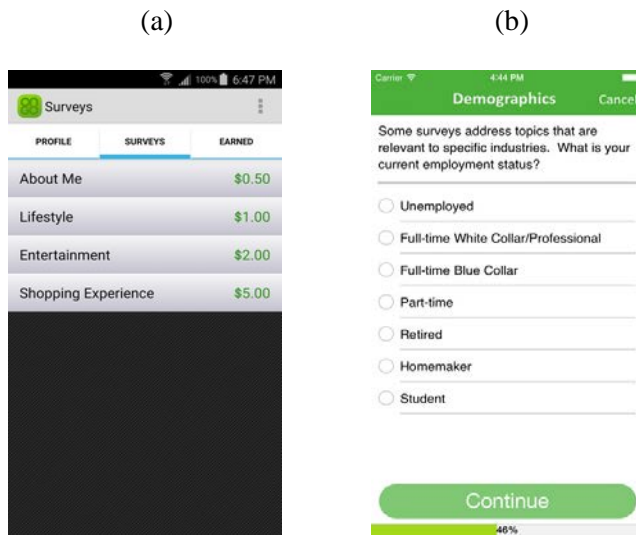


Figure 3: MFour Surveys-on-the-Go® smartphone app interface and example survey question

2.2 Survey Implementation: Sampling and Recruitment

For this proof of concept study, geofences were drawn at a fifty-meter radius around grocery, convenience, and home improvement store entrances across the U.S.. Many large and well-known national chains were included (24 grocery, 10 convenience, and 4 home improvement or hardware store chains). Current members of the *Surveys on the Go*® panel received a push notification from the app inviting them to complete a brief survey. The app produces a visual notification and a cash register “cha-ching” sound.

The invitation was offered (i.e., the geofence was “tripped”) immediately upon entering the geofence area. However, the sampled panel member did not need to respond immediately. To create a protocol more similar to traditional population-based surveys, sampled panel members did not have to respond immediately, and received several reminders. The survey was open for 48 hours, and reminders were sent at 1 hour, 24 hours, and 40 hours after the initial invitation. Sampled panel members were, obviously, allowed to respond to the questionnaire when they were outside the geofence.

The survey remained in the field until the quota of 1,000 completed questionnaires was obtained. Analyses in this report are based on 998 respondents.

2.3 Weighting for Comparisons to BRFSS

Geofenced results were poststratified to control totals for sex, age, race, and education using population statistics from the 2017 American Community Survey (ACS). Similarly, the BRFSS data were weighted to be representative of the U.S. using standard BRFSS margins plus state in collapsed categories (Iachan, Pierannunzi, Healey, Greenlund, & Town, M., 2016). BRFSS margins include sex by age, race/ethnicity, education, marital status, home ownership, sex by race/ethnicity, race/ethnicity by age, and type of phone in the household (cell only, landline only, or both).

2.4 Benchmarking the Geofenced Sample to BRFSS

The goal of this benchmarking approach was to see if estimates calculated from the geofenced sample closely reflect BRFSS estimate, which was defined through a three-tiered approach based on 95% confidence interval overlap.

Tier 1 – “*Hit the nail on the head*”: Geofenced point estimate fell within BRFSS confidence interval

Tier 2 – “*Close but no cigar*”: Confidence intervals overlap at all

Tier 3 – “*Close only counts in horseshoes*”: Confidence intervals do not overlap

Twenty-three survey questions were used as the source for 56 separate demographic and health estimates see Appendix 1 for question wording and Appendix 2 for geofenced and BRFSS estimates). No adjustments were made for multiple testing.

Finally, health outcomes in Tier 3, those with no confidence interval overlap, were explored further to assess the degree of over- and underrepresentation of geofenced estimates relative to BRFSS. This was calculated as the absolute value of the difference between the geofenced and BRFSS estimates, divided by the BRFSS estimate times 100. This relative difference was calculated because raw differences can be difficult to interpret (i.e., a small difference has a larger effect on estimate change for smaller base percentages than larger ones). The BRFSS estimate was chosen as the base because it is the probability health survey gold standard against which the geofenced estimates are compared.

3. Results

3.1 Overall geofenced sample representativeness

Not surprisingly Tier 1 (i.e., estimates for which the geofenced point estimate fell within the BRFSS 95% confidence interval) was comprised only of demographic estimates that were used as weighting dimensions. Of the three Tiers 2 (i.e., overlapping confidence intervals) contained the most estimates. Geofenced estimates tended to follow increases and decreases in BRFSS estimates, even when they did not accurately reflect individual estimates. Seventy-two percent (26) of Tier 2 estimates were demographic and 28% (10) were health outcomes. Finally, Tier 3, in which geofenced and BRFSS estimates confidence intervals did not overlap at all, contained mostly health estimates (44%).

Table 2: Number and Percentage of Estimates Within Each Accuracy Tier

Tier	Accuracy Definition	# of Estimates	Estimate Type					
			Demographic/Economic			Substantive Health		
			#	% of Type	% of Tier	#	% of Type	% of Tier
1	“Hit the nail on the head” Geofenced point estimate within BRFSS 95% CI	4	4	10%	100%	0	0%	0%
2	“Close but no cigar” 95% CIs overlap	36	26	6 7%	72%	10	59%	28%
3	“Close only counts in horseshoes” 95% CIs do not overlap	16	9	23%	56%	7	41%	44%
	Total	56	39			17		

Simply having overlapping confidence intervals is a fairly low bar for demonstrating accuracy, particularly when the one of the two surveys being compared has a much smaller sample size than the other, producing wide confidence intervals. In this study, the MFour sample of 998 respondents produced confidence intervals many times wider than BRFSS intervals. Thus, many of the Tier 2 estimates demonstrate overlap simply due to geofenced sample’s confidence interval width. However, three estimates emerged as mirroring the BRFSS very closely: lack of monthly exercise; lower self-rated general health, and lack of health insurance. Figure 4 shows these estimates side-by-side. Note that the BRFSS estimates appear to have no confidence interval because their intervals are so small that they are covered by the point estimate icon.

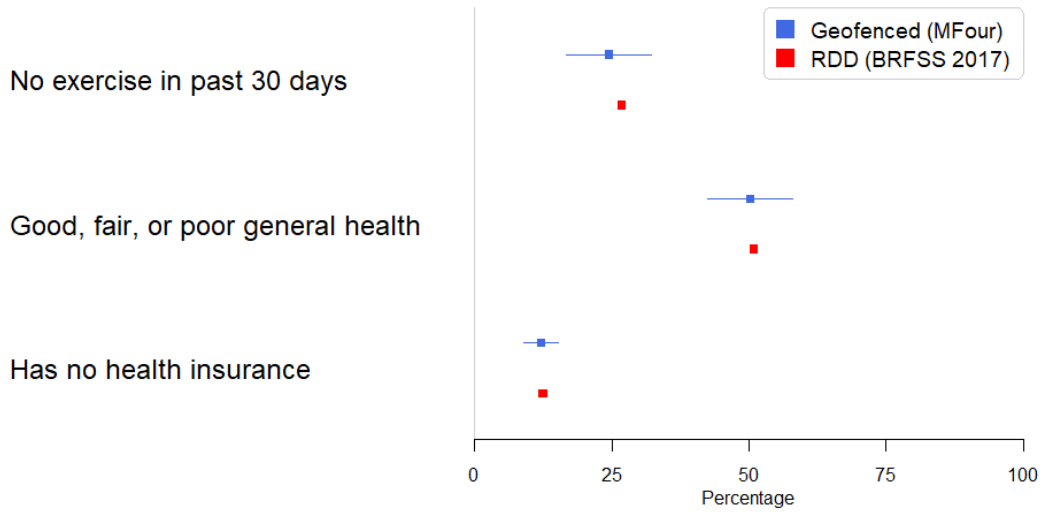


Figure 4: Tier 2 (95% CI overlap) estimates that offer optimism for this approach

3.2 Degree and direction of error when it misses the mark

Figure 5 shows the amount of over- or under-representation in the geofence estimates relative to BRFSS. Only health estimates in Tier 3 are included. The left-hand trend shows estimates for which the geofenced sample produced an overestimate (min = 34%, max = 164%) relative to BRFSS. Only fruit juice consumption was underestimated by the geofence sample (data point on the right). Clearly, when the geofenced sample estimates did not approximate BRFSS, they tended to overestimate negative health behaviors (e.g., alcohol consumption, smoking and tobacco use, drinking sugar-sweetened beverages, and less fruit juice consumption) and reduced access to care.

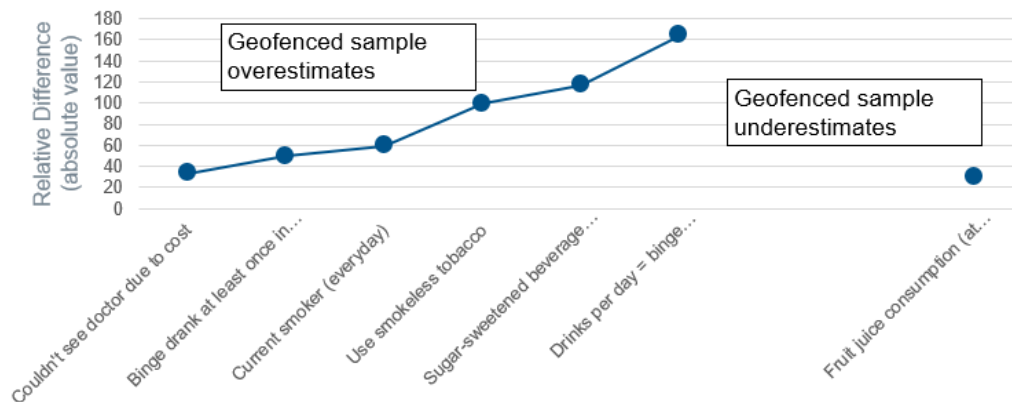


Figure 5. Geofence over/underestimate as % of BRFSS estimate

4. Discussion

There is clear promise in geofenced samples as a replacement for or supplement to probability samples for health surveys. Lack of exercise, lower general health, and lack of health insurance matched BRFSS estimates almost exactly after weighting. However, many health estimates did not closely mirror BRFSS, and among those there is a clear pattern of the geofence sample producing estimates of worse health outcomes or less healthy behaviors (i.e., over-estimating poor health). Based on this study, the estimates to be most concerned about include: extreme tobacco use, binge drinking, consuming high-calorie drinks, and not being able to see a doctor due to cost. Thus, while geofenced sampling may be able to produce accurate population estimates for some general health behaviors and outcomes, it is not a panacea.

References

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Appendix 1: Survey Questions Used

Table A-1: Survey questions used

<i>Construct</i>	<i>Question</i>	<i>Response Options</i>
Age	What is your age? (BRFSS)	__Code age in years (BRFSS)
Sex	Age for geofenced sample obtained from MFour panel member database Are you male or female?	1. Male 2. Female
Marital Status	Are you...? Select one.	1. Married 2. Divorced 3. Widowed 4. Separated 5. Never married 6. A member of an unmarried couple 7. In a registered domestic partnership
Education	What is the highest grade or year of school you completed?	1. Never attended school or only attended kindergarten 2. Grades 1 through 8 (Elementary) 3. Grades 9 through 11 (Some high school) 4. Grade 12 or GED (High school graduate) 5. College 1 year to 3 years (Some college or technical school) 6. College 4 years or more (College graduate)
Owns Home	Do you own or rent your home?	1. Own 2. Rent
Employment	Are you currently...? Select one.	1. Employed for wages 2. Self-employed 3. Out of work for 1 year or more 4. Out of work for less than 1 year 5. Homemaker 6. A Student 7. Retired 8. Unable to work
Income	Is your annual household income from all sources...	1. Yes 2. No

[SEQUENTIAL UNFOLDING]

BRACKETS]

Less than \$25,000 (\$20,000 to less than \$25,000)?

Less than \$20,000 (\$15,000 to less than \$20,000)?

Less than \$15,000 (\$10,000 to less than \$15,000)?

Less than \$10,000?

//ask if entry question is = "No"//

Less than \$35,000 (\$25,000 to less than \$35,000)?

Less than \$50,000 (\$35,000 to less than \$50,000)?

Less than \$75,000 (\$50,000 to less than \$75,000)?

Race

Which one or more of the following would you say is your race? Select all that apply.

1. White
2. Black or African American
3. American Indian or Alaska Native
4. Asian
5. Pacific Islander

Ethnicity

Are you Hispanic, Latino/a, or Spanish origin?

1. Yes
2. No

Smoked at least 100 cigarettes in lifetime

Have you smoked at least 100 cigarettes in your entire life? Do not include electronic cigarettes (e-cigarettes, NJOY, Bluetip), herbal cigarettes, cigars, cigarillos, little cigars, pipes, bidis, kreteks, water pipes (hookahs), or marijuana. Please note that 100 cigarettes is equal to 5 packs of cigarettes.

1. Yes
2. No

Smoker status

Do you now smoke cigarettes every day, some days, or not at all?

1. Every day
2. Some days
3. Not at all

Currently uses smokeless tobacco

Do you currently use chewing tobacco, snuff, or snus every day, some days, or not at all?

1. Every day
2. Some days
3. Not at all

Drinks per day = binge (avgisbinge)
Binge drank at least once in past 30 days (first

During the past 30 days, on the days when you drank, about how many drinks did you drink on the average? Please note: One drink is equivalent

_____ Number of drinks
Don't know/Not sure

definition: binge) Binge drank in past 30 days (maxisbinge)	to a 12-ounce beer, a 5-ounce glass of wine, or a drink with one shot of liquor. A 40-ounce beer would count as 3 drinks, or a cocktail drink with 2 shots would count as 2 drinks.	
	Considering all types of alcoholic beverages, how many times during the past 30 days did you have [IF MALE, INSERT "5 or more", ELSE IF FEMALE, INSERT "4 or more"] drinks on an occasion?	____ Number of times None Don't know/Not sure
	During the past 30 days, what is the largest number of drinks you had on any occasion?	
Fruit juice consumption (at least 1 serving per day past 30)	Not including fruit-flavored drinks or fruit juices with added sugar, how often in the past 30 days did you drink 100% fruit juice such as apple or orange juice? Enter '0' if you did not drink 100% fruit juice in the last 30 days.	____ Number of drinks None Don't know/Not sure ____ times per: 1. Day 2. Week 3. Month Don't know/Not sure
Sugar-sweetened beverage consumption (at least 1 serving per day past 30)	Now, thinking about sugar-sweetened beverages including regular soda, sports drinks, energy drinks, coffee, tea, and juices that have added sugar, how often in the past 30 days did you drink sugar-sweetened beverages? Enter '0' if you did not drink any sugar-sweetened beverages in the last 30 days.	____ times per: 1. Day 2. Week 3. Month Don't know/Not sure
Good, fair, or poor general health	Would you say that in general your health is excellent, very good, good fair, or poor?	1. Excellent 2. Very good 3. Good 4. Fair 5. Poor
Does not have health insurance	Do you have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, government plans such as Medicare, or Indian Health Service?	1. Yes 2. No
Couldn't see doctor due to cost in past 12 months	Was there a time in the past 12 months when you needed to see a doctor but could not because of	1. Yes 2. No

No exercise in past 30 days	<p>cost?</p> <p>During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?</p>	<p>1. Yes 2. No</p>
No flu shot/spray in past 12 months	<p>If you do not have a regular job or are retired, count any physical activity or exercise you do.</p> <p>During the past 12 months, have you had either a flu shot or a flu vaccine that was sprayed in your nose?</p>	<p>1. Yes 2. No</p>
Seatbelt nonuse	<p>A new flu shot came out in 2011 that injects vaccine into the skin with a very small needle. It is called Fluzone Intradermal vaccine. This is also considered a flu shot.</p> <p>How often do you use seat belts when you drive or ride in a car?</p>	<p>1. Always 2. Nearly always 3. Sometimes 4. Seldom 5. Never</p>

Appendix 2: Detailed geofenced and RDD estimates

Table A-2: MFour and BRFSS Point Estimates, Confidence Intervals, and Accuracy Tier

Question (n = 23)	Estimate (n = 56)	MFour (Geofenced)			BRFSS (2017)			Tier
		%	LCL (95%)	UCL (95%)	%	LCL (95%)	UCL (95%)	
Age	18 - 24 years	12.58	10.03	15.14	12.14	11.90	12.39	2
	25 - 34 years	17.80	17.80	17.80	17.80	17.80	17.80	2
	35 - 49 years	24.91	20.35	29.46	23.69	23.41	23.96	2
	50 - 64 years	25.41	19.66	31.17	25.62	25.35	25.88	1
	65+ years	19.29	8.04	30.55	20.28	20.09	20.48	2
Female		51.33	43.38	59.28	51.28	50.97	51.60	1
Marital Status	Married	46.66	38.83	54.49	50.53	50.22	50.84	2
	Divorced	14.35	5.98	22.72	10.71	10.54	10.89	2
	Widowed	2.24	0.00	4.65	6.81	6.69	6.94	3
	Separated	2.19	0.97	3.41	2.63	2.53	2.73	2
	Never married	24.86	19.65	30.06	24.21	23.92	24.50	2
	Unmarried couple	8.84	6.64	11.04	5.11	4.95	5.26	3
Education	High School or Less	40.49	32.08	48.90	41.45	41.13	41.76	2
	Some College	31.15	24.51	37.79	31.07	30.78	31.36	1
	College Degree or More	28.35	22.62	34.08	27.49	27.24	27.73	2
Owns home		58.42	50.84	66.00	66.32	66.04	66.61	3
Employment	Employed for wages	50.62	42.73	58.51	48.06	47.75	48.37	2
	Self-employed	15.48	10.51	20.45	9.10	8.92	9.29	3
	Out of work ≥ 1 year	1.03	0.44	1.62	2.75	2.64	2.86	3
	Out of work < 1 year	1.97	1.05	2.90	2.92	2.80	3.04	2
	Homemaker	5.41	3.67	7.15	6.44	6.26	6.61	2
	Student	4.78	3.47	6.09	5.66	5.48	5.84	2
	Retired	16.92	6.26	27.57	18.01	17.82	18.20	2
	Unable to work	3.79	1.96	5.61	7.06	6.90	7.21	3
Income	< \$10,000	3.41	1.95	4.87	5.75	5.57	5.93	3
	\$10K to < \$15K	4.04	2.17	5.91	5.06	4.91	5.22	2
	\$15K to < \$20K	6.33	2.22	10.44	7.71	7.50	7.92	2
	\$20K to < \$25K	5.51	3.25	7.77	9.29	9.09	9.49	3
	\$25K to < \$35K	11.08	3.16	18.99	10.38	10.16	10.59	2
	\$35K to < \$50K	16.83	8.84	24.83	13.29	13.06	13.52	2
	\$50K to < \$75K	21.13	15.52	26.75	14.73	14.50	14.96	3
	\$75K+	31.67	25.09	38.24	33.79	33.48	34.10	2
Race	White only	76.40	71.25	81.55	74.13	73.84	74.42	2
	Black only	13.32	9.58	17.06	13.09	12.87	13.31	2
	AIAN* only	1.61	0.71	2.50	2.10	2.00	2.20	2
	Asian only	3.91	2.54	5.27	4.03	3.88	4.18	1
	NHPI** only	0.51	0.00	1.04	0.43	0.39	0.47	2
	Multiracial	4.25	1.37	7.14	2.69	2.58	2.79	2

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Ethnicity	Hispanic	15.50	11.05	19.95	16.16	15.88	16.43	2
Smoked at least 100 cigarettes lifetime		44.75	36.94	52.55	40.60	40.29	40.90	2
Smoker status	Every day	17.90	13.01	22.78	11.09	10.90	11.29	3
	Some days	7.55	5.26	9.85	5.34	5.19	5.50	2
	Former smoker	19.30	11.55	27.05	24.10	23.84	24.36	2
	Never smoked	55.25	47.45	63.06	59.46	59.15	59.77	2
Currently uses smokeless tobacco		7.59	5.32	9.87	3.75	3.63	3.87	3
Drinks per day = binge (avgisbinge)		32.69	23.19	42.19	12.27	11.95	12.58	3
Binge drank at least once in past 30 days		48.19	38.59	57.79	31.89	31.47	32.30	3
Binge drank in past 30 days (maxisbinge)		35.23	27.78	42.68	30.07	29.66	30.48	2
Fruit juice consumption (at least 1 serving per day past 30)		11.77	7.95	15.59	17.16	16.90	17.42	3
Sugar-sweetened beverage consumption (at least 1 serving per day past 30)		33.78	27.47	40.08	15.27	14.63	15.91	3
Good, fair, or poor general health		50.21	42.38	58.04	50.78	50.46	51.09	2
Does not have health insurance		12.12	8.97	15.27	12.40	12.16	12.63	2
Couldn't see doctor due to cost in past 12 months		18.50	13.94	23.06	13.67	13.43	13.91	3
No exercise in past 30 days		24.42	16.72	32.13	26.73	26.44	27.01	2
No flu shot/spray in past 12 months		65.56	57.79	73.32	59.82	59.51	60.14	2
Seatbelt nonuse		14.46	9.78	19.14	11.58	11.37	11.78	2
*American Indian or Alaskan Native								
**Native Hawaiian or Pacific Islander								