2023 South Carolina Adult Tobacco Survey Small Area Estimates

Tobacco Prevention and Control Section

South Carolina Department of Public Health

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1. Overview

The 2023 South Carolina Adult Tobacco Survey (SC—ATS) was designed to produce precise state-level estimates but does not have adequate sample size to make direct estimates to small domains with adequate precision. Direct estimates only use data related to the domain in question and the study design information (e.g., sampling weights and stratification). We apply a modeling approach to make indirect estimates to small domains. The statistical model leverages a model to make "indirect" estimates for domains that lack adequate sample size for direct estimation.

The small areas described in this report include the 46 individual South Carolina counties and 32 domains composed of the cross-classification of sex, age category (18-24, 25-44, 45-64, 65 and older), and race/ethnicity (White NH, Black NH, Hispanic, other NH).

For each small area, estimates and 95% confidence intervals are created for the following tobacco related outcomes:

- Ever cigarette smoking
- Current cigarette smoking
- Ever e-cigarette use
- Current e-cigarette use
- Secondhand smoke exposure at work
- Secondhand smoke exposure in public

The modeling approach we applied is similar to the approach described in Srebotnjak et al. (2010) with differences described in Appendix A. Appendix A is separated from the main report because most readers will not have the technical background to assess the information discussed.

2. Methodology

2.1 County-Level Estimates

For each of the six outcomes described in Section 1, our method of calculating county-level estimates include the following steps:

- Weighted logistic models were fit to the 2023 SC—ATS data, one model for each outcome. The independent variables in the models were: region, age category, sex, and educational attainment. The dependent variable is the outcome.
- For each South Carolina County, a dataset with 60 records was created from the cross-classification of the following variables: sex (two categories), age (five categories), race/ethnicity (two categories), educational attainment (three categories). These data are referred to as synthetic data. They are called synthetic data because each data point is created in statistical analysis software, in contrast to data collected from survey respondents.
- For each synthetic datapoint an estimate of the probability of observing that outcome was calculated using the fitted model parameters.
- For each county, the synthetic data is calibrated to the county's marginal distribution totals of sex, age category, race/ethnicity category, and educational attainment category, obtained from U.S. Census Bureau data.
- The weighted synthetic data is used to estimate the prevalence of each outcome for every county.
- The precision of the estimates (i.e., 95% confidence intervals) is calculated using a statistical technique called bootstrap variance estimation described in Appendix B.

2.2 Sex by Age Category by Race/Ethnicity Estimates

For each of the six outcomes described in Section 1, we applied a method to calculate estimates for the 32 domains composed of the cross-classification of sex, age category, and race/ethnicity that includes the following steps:

- Weighted logistic models were fit to the 2023 SC—ATS data, one model for each outcome. The independent variables in the models were: region, age category, sex, and educational attainment. The dependent variable is the outcome.
- A dataset with 768 records was created from the cross-classification of the following variables: region (4 categories), sex (2 categories), age (6 categories), race/ethnicity (4 categories), educational attainment (4 categories). These data are referred to as synthetic data.
- For each synthetic datapoint an estimate of the probability of observing that outcome was calculated using the fitted model parameters.

- The synthetic data is calibrated to the state's marginal distribution totals of sex, age category, race/ethnicity category, and educational attainment category, obtained from U.S. Census Bureau data.
- The weighted synthetic data is used to estimate the prevalence of each outcome for each of the 32 domains composed of the cross-classification of sex, age category (18-24, 25-44, 45-64, 65 and older), and race/ethnicity (White NH, Black NH, Hispanic, other NH).
- The precision of the estimates (i.e., 95% confidence intervals) is calculated using a statistical technique called bootstrap variance estimation described in Appendix B.

3. Data Used in the Analysis

In 2023, the SC—ATS was conducted using an address-based sample (ABS) survey. The sample was allocated to maximize the precision of the state-level estimates; there was no geographic stratification and no oversampling of any geographies. The sample was a simple random sample of addresses on the USPS Delivery Sequency File. In expectation, the number of respondents in each county is proportional to the number of addresses in each county. There were 1,370 respondents across the 46 counties.

Exhibits 3.1 and 3.2 display the number of 2023 SC—ATS respondents for each of the domains to which we are making small area estimates. All of the domains, to which we are making small area estimates, have less than 200 respondents. If there were more respondents in some of the domains than it would be useful to make direct estimates to compare with the indirect estimates. Comparing the direct and indirect estimates, for the domains with adequate sample sizes, is a method of evaluating the correctness of the model and ultimately the correctness of the indirect estimates. However, with only one year of data, we do not have enough sample in any of the domains to conduct this evaluation. After two years of data collection, we will have adequate sample sizes in some of the domains to make this evaluation.

Table 1. Number of SC--ATS Respondents by County

Displays the number of SC—ATS respondents by county. The counties are ordered by the number of respondents.

County name	Adult population	2023 SC—ATS respondents
Richland	327,281	148
Greenville	425,058	125
Charleston	338,978	110
Horry	316,837	100
York	226,190	81
Spartanburg	266,429	69
Lexington	237,270	63
Berkeley	188,229	62
Dorchester	127,435	54
Anderson	163,262	48
Aiken	137,853	47
Beaufort	161,504	43
Sumter	79,752	36
Florence	105,110	30
Orangeburg	64,852	28
Oconee	65,322	26
Greenwood	53,589	25
Georgetown	54,164	20
Laurens	53,336	20
Pickens	106,087	20
Cherokee	43,435	19
Chesterfield	34,273	16
Lancaster	82,828	15
Kershaw	52,526	14
Darlington	48,668	13
Clarendon	25,350	11
Newberry	29,942	11
Hampton	14,478	10
Marion	22,247	10
Colleton	30,064	9
Edgefield	22,472	9
Williamsburg	24,411	9
Barnwell	15,650	7
Jasper	26,393	7
Marlboro	20,954	7
Lee	13,104	6
Saluda	14,902	6
Union	21,303	6
Abbeville	19,558	5
Fairfield	16,858	5
McCormick	8,777	5
Bamberg	10,408	4
Chester	25,028	4
Dillon	20,896	4
Calhoun	11,599	2
Allendale	6,255	1
Over all counties	4,160,917	1,370

Table 2. Number of SC--ATS Respondents by County
Displays the number of SC—ATS respondents by sex, by age category, and by race/ethnicity category.

Sex	Age category	Race/ ethnicity	Population	2023 SC-ATS Respondents
Female	18 to 24	White NH	134,831	23
		Black NH	71,108	15
		Hispanic	19,693	3
		Other NH	13,310	2
	25 to 44	White NH	405,613	156
		Black NH	192,269	81
		Hispanic	46,084	19
		Other NH	32,104	9
	45 to 64	White NH	456,077	196
		Black NH	179,003	99
		Hispanic	30,218	13
		Other NH	22,462	9
	65 and older	White NH	415,182	175
		Black NH	120,040	47
		Hispanic	10,597	3
		Other NH	12,566	2
Male	18 to 24	White NH	144,004	13
		Black NH	70,396	7
		Hispanic	22,758	4
		Other NH	14,330	1
	25 to 44	White NH	400,632	83
		Black NH	172,551	29
		Hispanic	54,428	5
		Other NH	28,832	11
	45 to 64	White NH	440,768	128
		Black NH	147,417	31
		Hispanic	34,796	7
		Other NH	19,219	8
	65 and older	White NH	348,239	154
		Black NH	82,530	29
		Hispanic	9,124	4
		Other NH	9,731	4
Total			**4,160,912**	**1,370**

Table 3. Tobacco Outcome Estimates for South Carolina
Displays the state-level prevalence for the 6 tobacco outcome estimated in this report.

Tobacco outcome	n	%	95% confidence interval
Ever smoker	1,370	68.9	(65.5, 72.4)
Current smoker	1,370	11.8	(9.5, 14.2)
Ever e-cigarette user	1,370	20.4	(17.2, 23.6)
Current e-cigarette user	1,370	7.5	(5.4, 9.7)
Secondhand smoke at home	1,370	8.3	(6.3, 10.3)
Secondhand smoke in public	1,370	28.6	(25.4, 31.9)

4. County-Level Estimates

Table 4. Ever Smoking and Current Smoking Estimates (%) and 95% Confidence Intervals for South Carolina Counties

			Ever smoking		Current smoking	
FIPS	County name	Population	Estimate (%)	95% CI	Estimate (%)	95% CI
1	Abbeville	19,558	71.0	(65.4, 76.7)	15.8	(10.4,21.2)
3	Aiken	137,853	72.9	(66.1, 79.7)	12.7	(7.3,18.2)
5	Allendale	6,255	67.0	(59.2, 74.8)	9.3	(4.5,14.1)
7	Anderson	163,262	71.0	(65.3, 76.7)	15.5	(10.4,20.5)
9	Bamberg	10,408	68.1	(60.9, 75.3)	8.0	(4.1,11.9)
11	Barnwell	15,650	69.9	(63.1, 76.6)	9.0	(4.9,13.2)
13	Beaufort	161,504	72.0	(65.5, 78.5)	6.7	(3.5,9.8)
15	Berkeley	188,229	70.0	(63.4, 76.7)	8.3	(4.5,12.2)
17	Calhoun	11,599	70.9	(64.3, 77.6)	8.4	(4.5,12.3)
19	Charleston	338,978	69.7	(62.9, 76.4)	7.0	(3.7,10.2)
21	Cherokee	43,435	70.6	(64.8, 76.4)	16.6	(11.0,22.2)
23	Chester	25,028	72.7	(65.7, 79.6)	14.3	(8.3,20.3)
25	Chesterfield	34,273	66.4	(59.2, 73.6)	13.8	(8.4,19.3)
27	Clarendon	25,350	65.6	(58.7, 72.5)	12.6	(7.9,17.4)
29	Colleton	30,064	70.9	(64.3, 77.6)	9.3	(5.0,13.6)
31	Darlington	48,668	65.1	(58.2, 71.9)	12.3	(7.7,16.8)
33	Dillon	20,896	64.2	(57.0, 71.4)	13.4	(8.4,18.4)
35	Dorchester	127,435	70.1	(63.5, 76.7)	8.2	(4.5,11.9)
37	Edgefield	22,472	72.5	(65.4, 79.5)	14.1	(8.1,20.1)
39	Fairfield	16,858	71.1	(63.7, 78.4)	13.4	(7.6,19.2)
41	Florence	105,110	64.1	(57.3, 70.9)	11.9	(7.6,16.1)
43	Georgetown	54,164	68.4	(62.0, 74.7)	10.8	(6.8,14.8)
45	Greenville	425,058	68.8	(63.1, 74.5)	13.6	(9.2,18.1)
47	Greenwood	53,589	68.7	(63.0, 74.5)	14.6	(9.6,19.6)
49	Hampton	14,478	68.9	(61.8, 76.0)	9.5	(5.0,14.0)
51	Horry	316,837	69.5	(63.1, 76.0)	11.6	(7.0,16.2)
53	Jasper	26,393	70.1	(63.3, 77.0)	8.8	(4.7,12.9)
55	Kershaw	52,526	73.3	(66.5, 80.0)	13.6	(7.9,19.4)
57	Lancaster	82,828	73.7	(67.1, 80.4)	12.9	(7.3,18.4)
59	Laurens	53,336	70.3	(64.6, 76.0)	16.2	(10.7,21.6)
61	Lee	13,104	62.6	(55.2, 70.1)	12.7	(8.0,17.4)
63	Lexington	237,270	73.2	(66.4, 80.0)	12.5	(7.0,18.0)
65	McCormick	8,777	71.9	(66.1, 77.7)	14.3	(8.8,19.9)
67	Marion	22,247	63.7	(56.5, 71.0)	12.9	(8.1,17.7)
69	Marlboro	20,954	63.7	(56.2, 71.2)	13.7	(8.5,18.9)
71	Newberry	29,942	72.8	(65.9, 79.7)	13.7	(7.9,19.4)
73	Oconee	65,322	72.7	(67.1, 78.4)	14.7	(9.9,19.5)
75	Orangeburg	64,852	67.4	(60.1, 74.8)	7.9	(4.0,11.8)
77	Pickens	106,087	70.4	(64.5, 76.2)	14.5	(9.8,19.3)
79	Richland	327,281	67.1	(59.0, 75.3)	10.8	(5.8,15.8)
81	Saluda	14,902	73.3	(66.4, 80.1)	14.2	(8.2,20.2)
83	Spartanburg	266,429	69.2	(63.5, 74.9)	15.0	(10.0,20.0)
85	Sumter	79,752	63.2	(56.3, 70.1)	11.8	(7.7,16.0)
87	Union	21,303	70.6	(64.7, 76.4)	16.7	(10.9,22.5)
89	Williamsburg	24,411	63.0	(55.6, 70.4)	12.8	(8.0,17.5)
91	York	226,190	72.6	(65.7, 79.5)	12.1	(6.8,17.5)

Figure 4.1. Map of Ever Smoking Estimates for South Carolina Counties

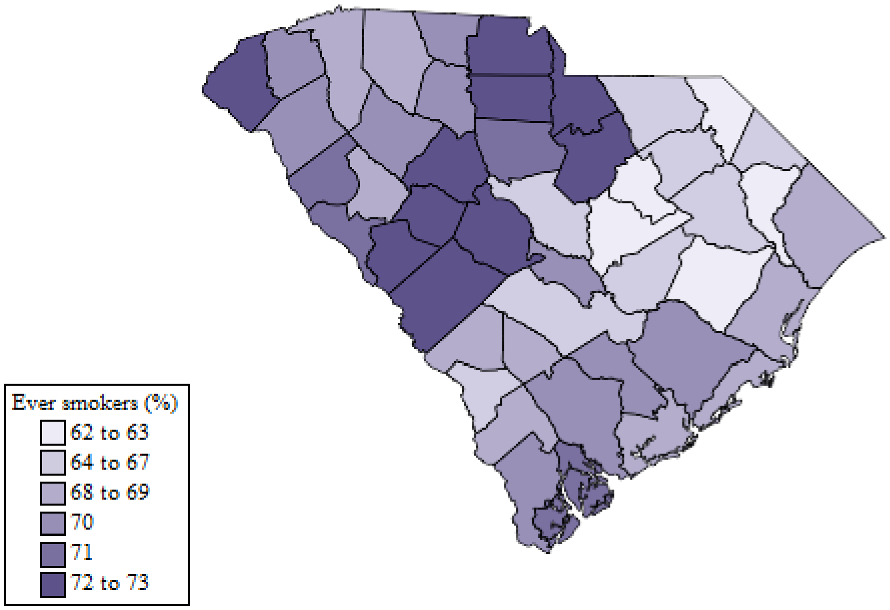


Figure 4.2. Map of Current Smoking Estimates for South Carolina Counties

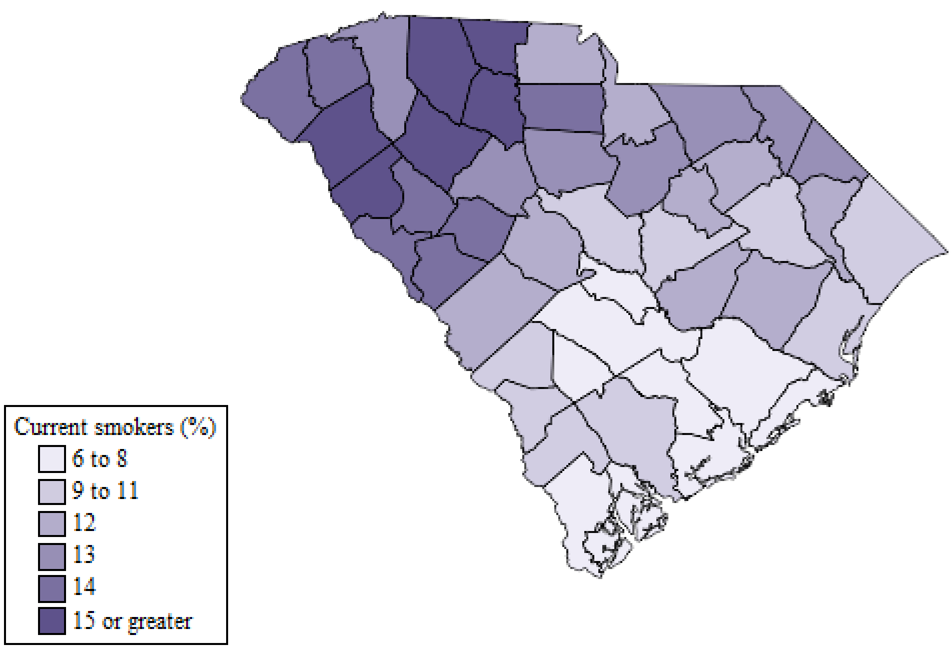


Table 5. Ever E-cigarette Use and Current E-cigarette Use Estimates (%) and 95% Confidence Intervals for South Carolina Counties

			Ever e-cigarette use		Current e-cigarette use	
FIPS	**County name**	**Population**	**Estimate (%)**	**95% CI**	**Estimate (%)**	**95% CI**
1	Abbeville	19,558	24.1	(18.9, 29.3)	7.2	(3.9,10.5)
3	Aiken	137,853	14.7	(8.7, 20.8)	7.8	(2.9,12.6)
5	Allendale	6,255	17.7	(10.6, 24.8)	8.8	(3.4,14.3)
7	Anderson	163,262	26.2	(20.7, 31.7)	7.8	(4.2,11.3)
9	Bamberg	10,408	16.9	(10.9, 23.0)	8.7	(3.7,13.6)
11	Barnwell	15,650	19.8	(13.1, 26.5)	10.0	(4.6,15.4)
13	Beaufort	161,504	17.3	(12.0, 22.7)	7.8	(3.9,11.7)
15	Berkeley	188,229	22.0	(15.1, 28.8)	10.9	(5.3,16.6)
17	Calhoun	11,599	17.8	(11.8, 23.9)	8.6	(4.0,13.1)
19	Charleston	338,978	20.3	(14.2, 26.5)	9.5	(4.8,14.2)
21	Cherokee	43,435	26.9	(21.1, 32.6)	8.2	(4.5,11.9)
23	Chester	25,028	15.1	(8.8, 21.3)	8.2	(3.1,13.3)
25	Chesterfield	34,273	20.9	(14.8, 27.0)	5.7	(2.0,9.3)
27	Clarendon	25,350	18.1	(12.8, 23.3)	4.9	(1.9,7.9)
29	Colleton	30,064	20.1	(13.3, 26.8)	9.8	(4.6,15.0)
31	Darlington	48,668	19.6	(14.0, 25.2)	5.4	(2.1,8.6)
33	Dillon	20,896	19.9	(14.0, 25.8)	5.6	(2.2,9.1)
35	Dorchester	127,435	21.4	(14.7, 28.0)	10.5	(5.1,15.9)
37	Edgefield	22,472	15.3	(8.9, 21.7)	8.0	(3.0,13.0)
39	Fairfield	16,858	12.2	(6.8, 17.5)	6.5	(2.4,10.7)
41	Florence	105,110	19.5	(13.9, 25.0)	5.3	(2.1,8.5)
43	Georgetown	54,164	16.4	(11.8, 21.0)	4.1	(1.6,6.6)
45	Greenville	425,058	25.1	(19.9, 30.3)	7.3	(4.0,10.6)
47	Greenwood	53,589	23.9	(18.8, 29.0)	7.2	(3.9,10.5)
49	Hampton	14,478	19.6	(12.5, 26.6)	9.7	(4.2,15.1)
51	Horry	316,837	18.9	(13.6, 24.2)	4.8	(1.8,7.9)
53	Jasper	26,393	18.4	(12.1, 24.7)	8.9	(4.1,13.7)
55	Kershaw	52,526	15.4	(9.1, 21.7)	8.2	(3.1,13.2)
57	Lancaster	82,828	14.8	(8.7, 20.9)	7.6	(2.9,12.3)
59	Laurens	53,336	25.3	(19.9, 30.8)	7.6	(4.2,11.1)
61	Lee	13,104	18.1	(12.5, 23.6)	4.9	(1.9,8.0)
63	Lexington	237,270	15.8	(9.4, 22.3)	8.3	(3.1,13.4)
65	McCormick	8,777	17.5	(13.4, 21.6)	4.5	(2.4,6.7)
67	Marion	22,247	17.9	(12.5, 23.4)	4.9	(1.9,8.0)
69	Marlboro	20,954	19.5	(13.6, 25.4)	5.3	(2.0,8.7)
71	Newberry	29,942	14.9	(8.7, 21.1)	7.9	(3.0,12.9)
73	Oconee	65,322	24.0	(18.9, 29.1)	6.7	(3.6,9.8)
75	Orangeburg	64,852	17.1	(10.9, 23.3)	8.8	(3.7,14.0)
77	Pickens	106,087	28.5	(22.7, 34.4)	8.8	(4.8,12.8)
79	Richland	327,281	14.3	(8.1, 20.5)	8.1	(2.9,13.3)
81	Saluda	14,902	14.7	(8.5, 20.9)	7.6	(2.8,12.5)
83	Spartanburg	266,429	26.1	(20.6, 31.5)	7.9	(4.3,11.4)
85	Sumter	79,752	19.5	(13.9, 25.0)	5.6	(2.2,8.9)
87	Union	21,303	24.3	(18.9, 29.6)	7.3	(3.9,10.7)
89	Williamsburg	24,411	17.3	(11.9, 22.8)	4.7	(1.8,7.7)
91	York	226,190	15.5	(9.2, 21.9)	8.1	(3.1,13.1)

Figure 5.1. Map of Ever E-cigarette Use Estimates for South Carolina Counties

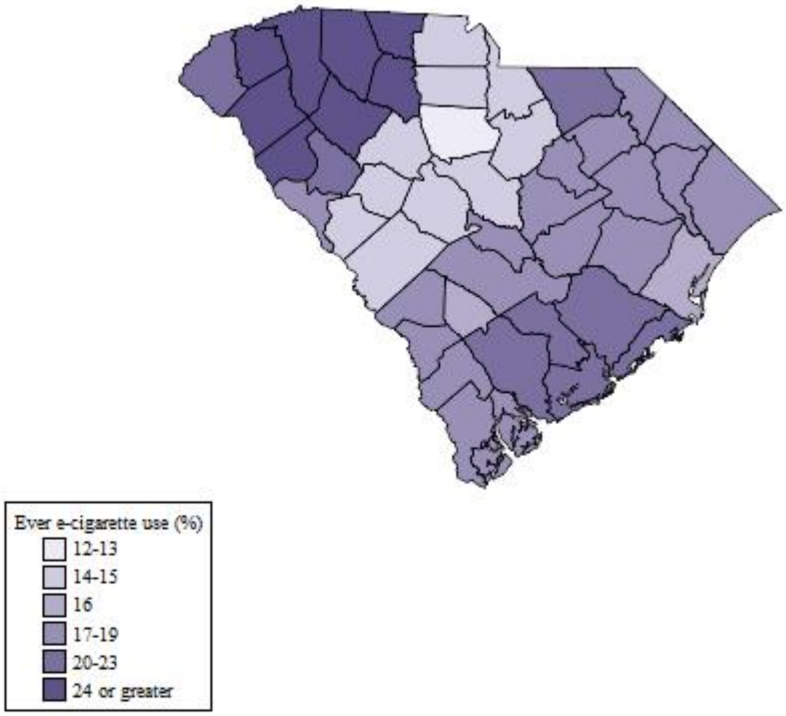


Figure 5.2. Map of Current E-cigarette Use Estimates for South Carolina Counties

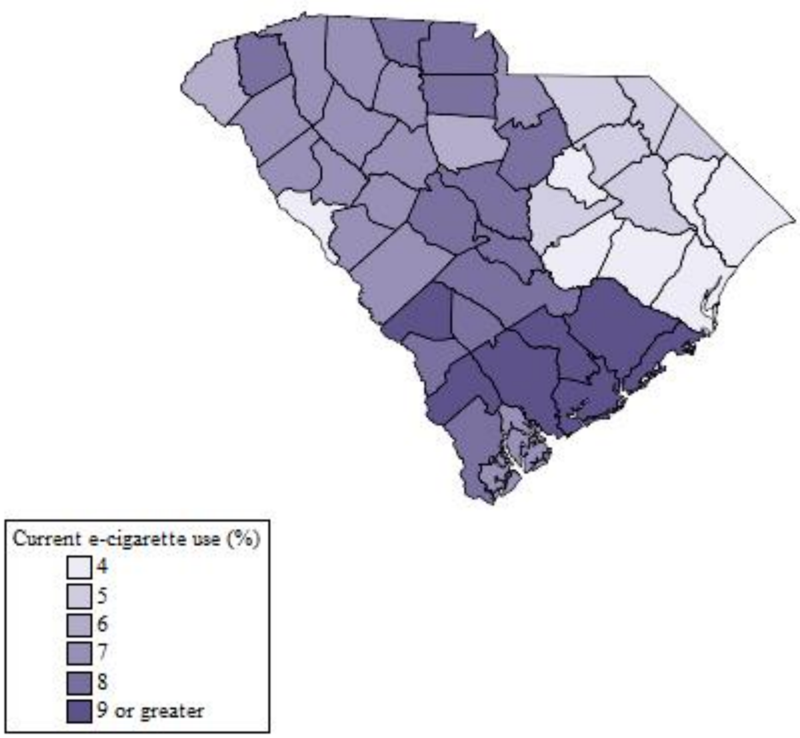


Table 6. Secondhand Smoke at Work and in Public Estimates (%) and 95% Confidence Intervals for South Carolina Counties 2023

			Secondhand smoke at work		Secondhand smoke in public	
FIPS	**County name**	**Population**	**Estimate (%)**	**95% CI**	**Estimate (%)**	**95% CI**
1	Abbeville	19,558	6.9	(3.8, 10.0)	30.5	(23.8, 37.2)
3	Aiken	137,853	12.4	(6.4, 18.5)	30.4	(23.2, 37.7)
5	Allendale	6,255	8.9	(4.2, 13.5)	27.3	(19.9, 34.8)
7	Anderson	163,262	7.4	(4.1, 10.8)	32.5	(25.8, 39.3)
9	Bamberg	10,408	8.3	(4.2, 12.3)	27.9	(21.2, 34.7)
11	Barnwell	15,650	9.5	(5.0, 13.9)	29.6	(22.7, 36.6)
13	Beaufort	161,504	8.0	(4.3, 11.7)	31.0	(24.5, 37.5)
15	Berkeley	188,229	10.3	(5.7, 14.8)	32.5	(25.5, 39.5)
17	Calhoun	11,599	8.7	(4.6, 12.7)	29.7	(23.1, 36.4)
19	Charleston	338,978	9.5	(5.3, 13.6)	33.5	(26.6, 40.4)
21	Cherokee	43,435	7.6	(4.2, 11.1)	31.8	(24.9, 38.8)
23	Chester	25,028	12.9	(6.5, 19.3)	29.4	(22.4, 36.5)
25	Chesterfield	34,273	6.6	(2.5, 10.7)	19.6	(13.7, 25.5)
27	Clarendon	25,350	5.7	(2.3, 9.1)	18.4	(13.1, 23.7)
29	Colleton	30,064	9.6	(5.1, 14.0)	30.3	(23.3, 37.3)
31	Darlington	48,668	6.2	(2.6, 9.8)	19.5	(14.1, 25.0)
33	Dillon	20,896	6.3	(2.5, 10.1)	18.9	(13.4, 24.4)
35	Dorchester	127,435	10.1	(5.6, 14.6)	32.8	(25.8, 39.8)
37	Edgefield	22,472	13.0	(6.5, 19.6)	29.9	(22.7, 37.1)
39	Fairfield	16,858	11.1	(5.2, 17.0)	27.5	(20.6, 34.5)
41	Florence	105,110	6.2	(2.7, 9.7)	19.9	(14.5, 25.3)
43	Georgetown	54,164	5.1	(2.2, 8.1)	19.2	(13.9, 24.5)
45	Greenville	425,058	7.1	(3.8, 10.4)	33.1	(26.5, 39.6)
47	Greenwood	53,589	6.8	(3.7, 10.0)	31.0	(24.4, 37.5)
49	Hampton	14,478	9.6	(4.9, 14.2)	29.3	(22.0, 36.5)
51	Horry	316,837	5.8	(2.4, 9.2)	20.3	(14.5, 26.2)
53	Jasper	26,393	8.7	(4.6, 12.9)	29.2	(22.4, 36.0)
55	Kershaw	52,526	13.0	(6.7, 19.4)	30.6	(23.4, 37.9)
57	Lancaster	82,828	12.7	(6.5, 18.9)	31.1	(23.8, 38.3)
59	Laurens	53,336	7.2	(4.0, 10.5)	31.3	(24.5, 38.1)
61	Lee	13,104	5.8	(2.3, 9.3)	18.2	(13.0, 23.3)
63	Lexington	237,270	13.4	(6.9, 19.9)	32.3	(24.7, 39.9)
65	McCormick	8,777	5.1	(2.7, 7.4)	27.6	(21.3, 33.9)
67	Marion	22,247	5.9	(2.4, 9.3)	18.3	(13.0, 23.5)
69	Marlboro	20,954	6.2	(2.4, 10.1)	18.4	(13.0, 23.9)
71	Newberry	29,942	12.6	(6.4, 18.9)	29.6	(22.5, 36.7)
73	Oconee	65,322	6.7	(3.7, 9.7)	32.1	(25.5, 38.7)
75	Orangeburg	64,852	8.4	(4.3, 12.5)	28.3	(21.5, 35.1)
77	Pickens	106,087	7.6	(4.1, 11.2)	32.7	(25.9, 39.5)
79	Richland	327,281	12.4	(5.6, 19.2)	30.1	(22.4, 37.8)
81	Saluda	14,902	12.7	(6.4, 19.0)	29.7	(22.6, 36.9)
83	Spartanburg	266,429	7.4	(4.0, 10.8)	32.3	(25.6, 39.0)
85	Sumter	79,752	6.1	(2.6, 9.5)	19.0	(13.9, 24.2)
87	Union	21,303	7.0	(3.9, 10.2)	30.3	(23.4, 37.2)
89	Williamsburg	24,411	5.7	(2.3, 9.2)	17.8	(12.7, 22.9)
91	York	226,190	13.4	(6.8, 20.1)	32.7	(25.1, 40.4)

Figure 6.1. Map of Percent Secondhand Smoke at Work Estimates for South Carolina Counties

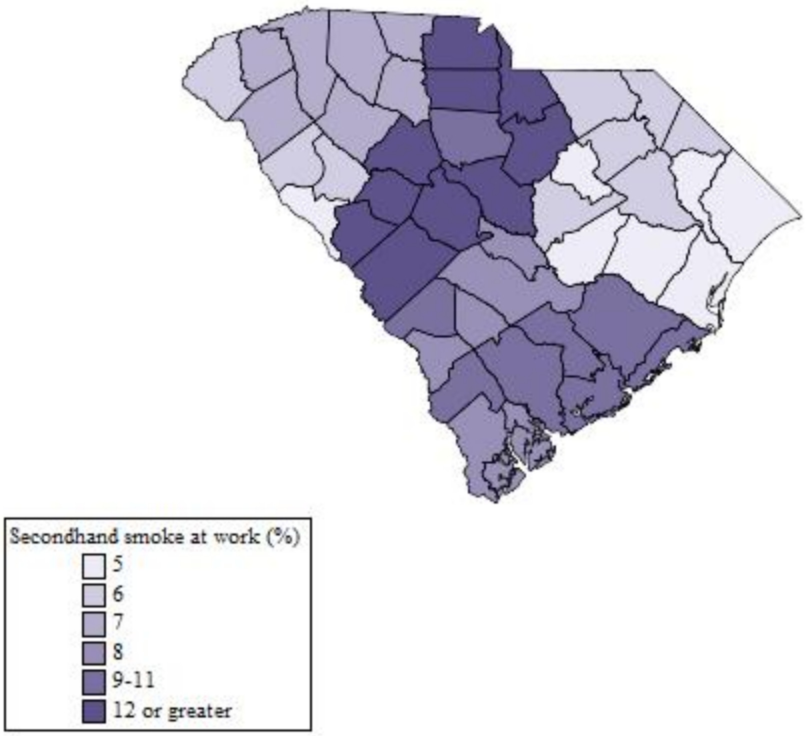
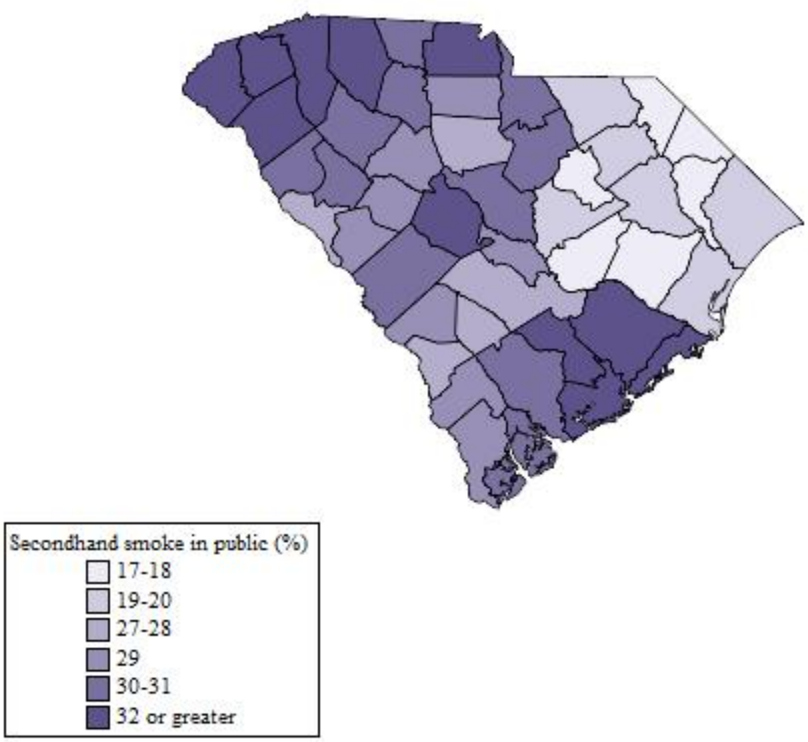


Figure 6.2. Map of Percent Secondhand Smoke in Public Estimates for South Carolina Counties



5. Tables of Sex by Age Category by Race/Ethnicity Estimates

Table 7. Ever Cigarette Use and Current Cigarette Use Estimates and 95% Confidence Intervals for Sex by Age Category by Race/Ethnicity

Domain			Ever cigarette use		Current cigarette use	
Sex	**Age category**	**Race/ ethnicity**	**Estimate (%)**	**Confidence interval**	**Estimate (%)**	**Confidence interval**
Female	18—24 years old	White NH	50.1	(34.6, 65.7)	7.3	(0.0, 14.8)
		Black NH	34.1	(19.6, 48.6)	5.4	(0.0, 11.0)
		Hispanic	41.6	(19.6, 63.6)	10.7	(0.0, 24.7)
		Other NH	41.0	(19.1, 62.8)	7.7	(0.0, 21.2)
	25—44 years old	White NH	69.0	(62.3, 75.8)	16.0	(10.9, 21.0)
		Black NH	53.9	(43.8, 64.0)	12.3	(6.1, 18.6)
		Hispanic	61.5	(43.0, 80.0)	22.0	(3.2, 40.8)
		Other NH	60.8	(43.4, 78.3)	16.7	(2.3, 31.1)
	45—64 years old	White NH	75.3	(69.3, 81.4)	13.4	(7.7, 19.2)
		Black NH	61.1	(52.4, 69.7)	10.2	(5.0, 15.5)
		Hispanic	68.4	(51.6, 85.2)	18.9	(2.4, 35.4)
		Other NH	67.8	(51.2, 84.4)	14.1	(0.5, 27.7)
	65 years old and older	White NH	79.9	(73.3, 86.5)	7.4	(3.0, 11.8)
		Black NH	67.1	(56.8, 77.4)	5.5	(1.2, 9.8)
		Hispanic	73.8	(57.5, 90.0)	10.8	(0.0, 22.5)
		Other NH	73.2	(56.7, 89.7)	7.8	(0.0, 17.7)
Male	18—24 years old	White NH	56.4	(39.4, 73.3)	7.7	(0.0, 15.3)
		Black NH	39.9	(23.5, 56.4)	5.7	(0.0, 11.6)
		Hispanic	47.8	(24.5, 71.1)	11.2	(0.0, 25.3)
		Other NH	47.1	(23.8, 70.5)	8.1	(0.0, 21.7)
	25—44 years old	White NH	74.0	(66.6, 81.4)	16.7	(10.8, 22.6)
		Black NH	59.8	(49.2, 70.5)	12.9	(5.2, 20.7)
		Hispanic	67.1	(49.4, 84.7)	22.9	(3.2, 42.6)
		Other NH	66.5	(50.0, 83.0)	17.4	(3.2, 31.6)
	45—64 years old	White NH	79.7	(73.5, 85.9)	14.1	(9.0, 19.1)
		Black NH	66.9	(58.2, 75.6)	10.8	(5.2, 16.3)
		Hispanic	73.6	(58.2, 88.9)	19.7	(3.1, 36.4)
		Other NH	73.0	(57.8, 88.2)	14.7	(1.5, 28.0)
	65 years old and older	White NH	83.6	(78.8, 88.5)	7.8	(3.4, 12.2)
		Black NH	72.4	(64.4, 80.3)	5.8	(1.2, 10.5)
		Hispanic	78.3	(64.4, 92.3)	11.4	(0.0, 23.1)
		Other NH	77.9	(64.0, 91.8)	8.2	(0.0, 18.2)

Table 8. Ever E-cigarette Use and Current E-cigarette Use Estimates and 95% Confidence Intervals for Sex by Age Category by Race/Ethnicity

Domain			Ever e-cigarette use		Current e-cigarette use	
Sex	Age category	Race/ ethnicity	Estimate (%)	Confidence interval	Estimate (%)	Confidence interval
Female	18—24 years old	White NH	50.1	(33.1, 67.1)	29.6	(12.7, 46.4)
		Black NH	25.6	(8.3, 42.9)	18.7	(1.1, 36.3)
		Hispanic	44.1	(18.7, 69.5)	16.0	(0.0, 36.6)
		Other NH	33.6	(10.2, 57.0)	21.6	(0.0, 48.4)
	25—44 years old	White NH	31.6	(23.5, 39.8)	16.7	(8.6, 24.8)
		Black NH	13.6	(7.6, 19.6)	9.8	(5.0, 14.7)
		Hispanic	26.6	(8.1, 45.2)	8.3	(0.0, 21.3)
		Other NH	18.8	(5.6, 32.1)	11.5	(0.0, 26.8)
	45—64 years old	White NH	16.9	(11.9, 21.9)	5.7	(2.2, 9.3)
		Black NH	6.5	(3.2, 9.9)	3.2	(0.6, 5.8)
		Hispanic	13.8	(1.6, 26.0)	2.6	(0.0, 8.0)
		Other NH	9.3	(1.8, 16.9)	3.8	(0.0, 11.1)
	65 years old and older	White NH	3.8	(1.4, 6.2)	0.0	(0.0, 0.0)
		Black NH	1.3	(0.2, 2.5)	0.0	(0.0, 0.0)
		Hispanic	3.0	(0.0, 6.5)	0.0	(0.0, 0.0)
		Other NH	1.9	(0.0, 4.0)	0.0	(0.0, 0.0)
Male	18—24 years old	White NH	55.5	(35.2, 75.8)	21.8	(5.2, 38.4)
		Black NH	29.9	(8.2, 51.7)	13.2	(0.0, 30.7)
		Hispanic	49.4	(21.3, 77.6)	11.2	(0.0, 27.9)
		Other NH	38.6	(12.0, 65.2)	15.4	(0.0, 36.9)
	25—44 years old	White NH	36.5	(27.5, 45.5)	11.6	(5.6, 17.7)
		Black NH	16.4	(8.7, 24.1)	6.7	(1.2, 12.1)
		Hispanic	31.1	(10.5, 51.6)	5.6	(0.0, 14.1)
		Other NH	22.4	(7.6, 37.3)	7.9	(0.0, 18.0)
	45—64 years old	White NH	20.1	(13.2, 27.0)	3.8	(1.4, 6.2)
		Black NH	8.0	(3.3, 12.7)	2.1	(0.0, 4.5)
		Hispanic	16.5	(2.3, 30.8)	1.7	(0.0, 4.8)
		Other NH	11.3	(2.3, 20.3)	2.5	(0.0, 7.0)
	65 years old and older	White NH	4.7	(1.7, 7.7)	0.0	(0.0, 0.0)
		Black NH	1.6	(0.1, 3.1)	0.0	(0.0, 0.0)
		Hispanic	3.7	(0.0, 8.1)	0.0	(0.0, 0.0)
		Other NH	2.4	(0.0, 5.0)	0.0	(0.0, 0.0)

Table 9. Secondhand Smoke Exposure at Work and In Public Estimates and 95% Confidence Intervals for Sex by Age Category by Race/Ethnicity

Domain			Secondhand smoke exposure at work		Secondhand smoke exposure in public	
Sex	Age category	Race/ ethnicity	Estimate (%)	Confidence interval	Estimate (%)	Confidence interval
Female	18—24 years old	White NH	6.2	(0.1, 12.3)	20.9	(10.1, 31.8)
		Black NH	5.3	(0.0, 10.9)	18.7	(8.0, 29.5)
		Hispanic	1.6	(0.0, 5.2)	5.3	(0.0, 12.0)
		Other NH	6.9	(0.0, 19.1)	16.3	(0.0, 32.7)
	25—44 years old	White NH	15.0	(9.0, 20.9)	36.5	(28.3, 44.7)
		Black NH	12.8	(6.6, 19.1)	33.4	(24.6, 42.1)
		Hispanic	4.1	(0.0, 13.5)	11.0	(2.0, 20.1)
		Other NH	16.3	(0.0, 32.7)	29.8	(12.7, 46.9)
	45—64 years old	White NH	10.2	(5.6, 14.8)	37.3	(30.0, 44.5)
		Black NH	8.7	(3.5, 14.0)	34.1	(25.1, 43.2)
		Hispanic	2.8	(0.0, 9.6)	11.5	(1.9, 21.1)
		Other NH	11.1	(0.0, 23.6)	30.6	(12.7, 48.4)
	65 years old and older	White NH	1.4	(0.0, 3.4)	16.9	(11.6, 22.3)
		Black NH	1.2	(0.0, 2.9)	15.1	(8.9, 21.3)
		Hispanic	0.3	(0.0, 2.5)	4.2	(0.0, 8.5)
		Other NH	1.6	(0.0, 5.5)	13.1	(1.8, 24.4)
Male	18—24 years old	White NH	7.2	(0.0, 14.4)	23.2	(11.3, 35.1)
		Black NH	6.1	(0.0, 13.7)	20.8	(9.0, 32.7)
		Hispanic	1.8	(0.0, 5.8)	6.1	(0.0, 13.4)
		Other NH	7.9	(0.0, 21.4)	18.2	(0.3, 36.2)
	25—44 years old	White NH	16.9	(10.1, 23.8)	39.5	(31.3, 47.8)
		Black NH	14.6	(5.0, 24.2)	36.3	(26.9, 45.8)
		Hispanic	4.7	(0.0, 14.6)	12.4	(2.6, 22.2)
		Other NH	18.4	(0.8, 36.1)	32.6	(14.4, 50.8)
	45—64 years old	White NH	11.5	(6.0, 17.1)	40.3	(32.1, 48.5)
		Black NH	9.9	(2.7, 17.2)	37.1	(26.6, 47.6)
		Hispanic	3.2	(0.0, 10.5)	12.9	(2.4, 23.5)
		Other NH	12.6	(0.0, 26.2)	33.4	(14.1, 52.7)
	65 years old and older	White NH	1.6	(0.0, 3.7)	18.9	(13.2, 24.5)
		Black NH	1.4	(0.0, 3.2)	16.8	(9.9, 23.8)
		Hispanic	0.4	(0.0, 2.6)	4.7	(0.0, 9.4)
		Other NH	1.8	(0.0, 5.7)	14.6	(2.5, 26.8)

6. Limitations

There are two concerns with the methodology we applied: bias and variance.

There are two ways the estimates can be biased. First, there could be bias in data that is input into the model. There is not much we can do about this. Second, the model might not be correct. The model estimates the effect of region, age category, race/ethnicity, sex, and education attainment across all counties. Then, these effects are applied to the distributions in a particular county. It might be the case that a particular county behaves differently after adjusting for the covariates in the model. The same issue might occur for the 32 domains composed of the cross-classification of sex, age category (18-24, 25-44, 45-64, 65 and older), and race/ethnicity (White NH, Black NH, Hispanic, other NH).

The variance of the estimates for some of the counties and other domains is large.

7. References

Dwyer-Lindgren, L., Freedman, G., Engell, R. E. *et al.* Prevalence of physical activity and obesity in US counties, 2001–2011: a road map for action. *Popul Health Metrics* 11, 7 (2013). https://doi.org/10.1186/1478-7954-11-7

Dwyer-Lindgren, L., Mokdad, A. H., Srebotnjak, T. *et al.* Cigarette smoking prevalence in US counties: 1996-2012. *Popul Health Metrics* 12, 5 (2014). https://doi.org/10.1186/1478-7954-12-5

Eberth, J., *et al*. Estimating county-level tobacco use and exposure in South Carolina: a spatial model-based small area estimation approach. *Annals of Epidemiology 28* (2018). https://doi.org/10.1016/j.annepidem.2018.03.015

Rao, J. N. K., Wu, C. F. J., & Yue, K. (1992). Some recent work on resampling methods for complex surveys, *Survey Methodology, 18*, pp. 209–217.

Srebotnjak, T., Mokdad, A. H. & Murray, C. J. A novel framework for validating and applying standardized small area measurement strategies. *Popul Health Metrics* 8, 26 (2010). https://doi.org/10.1186/1478-7954-8-26

Appendix A: Technical Details about the Application of the Modeling Procedure

The methodology we applied to estimate South Carolina county-level current smoking and current vaping prevalences comes from the Srebotnjak paper (Srebotnjak et al., 2010). The methodology described in the Srebotnjak paper was applied to the BRFSS data by Dwyer-Lindgren et al. to make county-level estimates of smoking rates and prevalence of physical activity and obesity (Dwyer-Lindgren et al., 2013) (Dwyer-Lindgren et al., 2014), and to estimate county-level tobacco use and exposure in South Carolina (Eberth et al., 2018).

There were some deviations in the methodology applied to the South Carolina ATS data and the methodology described in the Srebotnjak paper. The following summarizes the differences between the models we fit and the covariate model in the Srebotnjak paper. Each difference is described in detail below.

1. We did not treat county as a random effect.
2. We used a survey modeling procedure that accounted for the sampling weights and stratification; the models in the Srebotnjak paper did not.
3. We did not run separate models by sex; the models in the Srebotnjak paper did.
4. We included the individual-level characteristic educational attainment; the models in the Srebotnjak paper did not.

Differences 1 and 2

The Srebotnjak paper treated county as a random effect. Treating county as a random effect requires fitting a random effects model. Random effects models cannot use the study design (the sampling weights and the stratification). The methodology to fit a random effects model that incorporates the study design has not been developed. Not including the sampling weights and stratification in the model yields biased results.[1] We used SAS Proc SURVEYLOGISTIC, a procedure that allows the modeling of survey data but does not allow random effects.

We had data from 1,370 respondents. The original data used for the Srebotnjak paper contained more than one million observations, and the Eberth paper used data with 7,503 observations. The lack of data in this analysis resulted in an inability to include county and county-level covariates in the modeling procedure.

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[1] People without a background in survey statistics will often claim that the model incorporates the study design in the covariates. This simply is not the case, especially in the case of the Srebotnjak models that only include the individual characteristics of sex, age category, and race. In the Srebotnjak models, there no accounting for the unequal probabilities of selection due to the different sampling fractions across states. Someone from California has the same influence as someone from Wyoming, even though their weight is more than an order of magnitude larger.

From a theoretical point of view, counties are not random effects—they are fixed effects. The set of South Carolina counties is not a random sample from a theoretical collection of counties.

Difference 3

The Srebotnjak methodology ran separate models for sex: one for male and one for female. The Srebotnjak paper did not provide a good explanation for why they did this. It is possible they had convergence problems when fitting their models, which would have required them to run different models for the two sexes. Convergence is a problem when running random effects models because the procedure estimates the fixed effects and then, using that result, the random effects are estimated. It then estimates the fixed effects again using the estimates for the random effects. This process iterates until a convergence criterion is met. Sometimes the convergence criterion is never met, and the model fails to converge. In contrast, we incorporated sex as a covariate in the model and ran one fixed effects model that does not use an iterative model fitting procedure, and consequently, does not have convergence problems.

Difference 4

We included the individual-level characteristic educational attainment, in contrast to the models in Srebotnjak. Education attainment is the characteristic most correlated to smoking behaviors and most predictive of smoking behaviors. Failing to include education attainment would reduce the predictive ability of the model. Our inclusion of educational attainment is an improvement over the models in the Srebotnjak paper.

Appendix B: Describe Bootstrap Variance Estimation

We used a bootstrap method to calculate precision estimates. This method is described by J.N.K. Rao et al in a 1992 publication.[2]

In our application of the bootstrap method the following is applied for each outcome. Let H denote the number of sampling strata. There are H=10 sampling strata. Let n_h, h=1..H denote the number of respondents within each of the H sampling strata. Let $w_{i,h}$, i=1..n_h, h=1..H denote the analysis weight associated with the i^{th} respondent within the h^{th} sampling stratum. Let B=100 be the number of Bootstrap replicates that will be created.

Creating the Bootstrap Replicates and Bootstrap Weights

Each Bootstrap replicate and associated Bootstrap replicate weight was constructed by applying the following algorithm.

1) Within each sampling stratum h, select a with replacement sample of size n_h-1 from among the n_h respondents in the sampling stratum.
2) Count the number of times respondent i in stratum h was selected, denote this count as $m_{i,h}$
3) Create a data set with one record for each respondent selected in step 1.
4) For each sampled respondent, create the bootstrap weight, denoted $w^B_{i,h}$ using the following formula:

   $w^B_{i,h} = w_{i,h} * m_{i,h} * (n_h/(n_h-1))$

Apply the algorithm B times to create B replicate samples and B associated Bootstrap weights.

Creating the Estimates for each Replicate Sample

1) For each Bootstrap sample, create the predicted rates using the Bootstrap weight and respondents selected into the Bootstrap sample.
2) Create the county weights by applying the weight calibration used with the full respondent sample to the predicted values created using the Bootstrap sample and Bootstrap weight.
3) Estimate the county rates using the calibrated weight from step 2 with the predicted values from step 1.

Calculating the Bootstrap Variance Estimator for Each County by Year

Let θ_k denote the rate estimate for a given county in a given year produced using all respondents. Let $\theta_{k,b}$, b=1..B, denote the rate estimate for a given county in a given year produced using replicate sample b. The variance of θ_k is estimated using the following formula:

$$var(\theta_k) = \frac{1}{B}\sum_{b=1}^{B}\left(\theta_{k,b} - \theta_k\right)^2$$

[2] Rao, J. N. K., Wu, C. F. J. and Yue, K. (1992). Some recent work on resampling methods for complex surveys, Survey Methodology, 18, pp.209-217.