

## ORIGINAL RESEARCH

## Multilevel Small Area Estimation of Prostate-Specific Antigen Screening Test in the United States by Age Group: 2018 Behavioral Risk Factor Surveillance System

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**Background:** In 2018, the US Preventive Services Task Force (USPSTF) recommended prostate cancer screening for men aged 55 to 69 years who express a preference for being screened after being informed about and understanding prostate-specific antigen (PSA) test benefits and risks. USPSTF recommended against screening men aged  $\geq 70$  years. We aim to generate county-level prevalence estimates, masked by national and state estimates, to identify counties with high PSA screening prevalence.

**Methods:** We fitted multilevel logistic regression mixed models for 4 age groups ( $\geq 40$ , 40 to 54, 55 to 69,  $\geq 70$  years), using data from the 2018 Behavioral Risk Factor Surveillance System (BRFSS) ( $n = 116,654$ ) and other sources. We evaluated consistency between our model-based state and BRFSS direct state estimates with Spearman and Pearson correlation coefficients.

**Results:** PSA screening prevalence increased with increasing age groups: 7.7% for men aged 40 to 54 years, 27.2% for men aged 55 to 69 years, and 33.7% among men age  $\geq 70$  years, and was largely clustered in the South and Appalachia. Many county estimates among men aged  $\geq 70$  years exceeded 40%, especially in the South. Correlation coefficients were 0.94 for men aged  $\geq 40$ , and  $\geq 0.85$  for men aged 40 to 54 years, 55 to 69 years, and  $\geq 70$  years.

**Conclusions:** PSA screening was highest among men  $\geq 70$  years, for whom it is not recommended, and in the South among all age groups. Screening varied substantially within states.

**Impact:** In 2018, on average, more than 1 in 4 men aged 55 to 69 years and 1 in 3 men aged  $\geq 70$  years underwent PSA screening in the prior year, suggesting potential overuse among some men. (J Am Board Fam Med 2021;34:634–647.)

**Keywords:** Behavioral Risk Factor Surveillance System, County-Level Estimates, Early Detection of Cancer, Internal Consistency, Logistic Models, Multilevel Small Area Estimation, Prostate Cancer, Prostate-Specific Antigen, PSA, PSA Screening Prevalence

## Introduction

In 2008, the US Preventive Services Task Force (USPSTF) recommended against prostate-specific

antigen (PSA) screening test for prostate cancer for men aged 75 years or older,<sup>1</sup> and in 2012, the USPSTF recommended against PSA screening for men of all ages.<sup>2</sup> In 2018, the USPSTF recommended that men should be informed about and understand the benefits and harms of screening and express a preference to be screened before the test is offered.<sup>3,4</sup> This current recommendation is limited to men aged 55 to 69 years, for whom the net

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benefits might be small (Grade C recommendation, selective offering). For men aged  $\geq 70$  years, the USPSTF recommended against PSA screening (Grade D, discourage use), stating that the potential benefits do not outweigh the harms.<sup>4</sup> Potential harms include false positives, overdiagnosis and overtreatment, and treatment complications, such as loss of normal urinary, bowel, and sexual functions.<sup>3</sup> The USPSTF was not able to provide specific recommendations for men aged  $< 55$  years, for men with family history, or African-American men, who have increased risk of prostate cancer mortality.<sup>5,6</sup> Although screening might offer potential benefits to some men among the youngest and oldest age groups, screening might also expose these men to adverse effects.<sup>4</sup> PSA screening has been associated with disproportionate cost among men aged 70 years or older.<sup>7</sup>

Currently few publications review geospatial variations in PSA screening in the United States. Although recent studies identified predictors associated with PSA screening, few have described variations among states or US Census regions.<sup>8–12</sup> National, regional and state-level estimates can mask the variations in PSA screening within states.<sup>13</sup> Previous analyses of breast and colorectal cancer screening<sup>14,15</sup> found large variations between and within states with striking geographical distributions. To improve knowledge of PSA screening in smaller areas, we performed a county-level analysis to describe the prevalence of PSA screening by county, and by age groups for whom USPSTF conclusions varied. Small area estimates (SAE) can help identify areas of frequent screening, especially among men aged 70 or older for some of whom screening could reflect overuse. Estimates may also inform public health research, programmatic, and communication efforts.

## Materials and Methods

We used data from the 2018 Behavioral Risk Factor Surveillance System (BRFSS) about PSA screening among men aged 40 years or older.<sup>16</sup> The BRFSS is a state-based cross-sectional, health-related telephone survey collecting data from noninstitutionalized US adults aged 18 years or older. The Centers for Disease Control and Prevention (CDC) administers the BRFSS annually in collaboration with state health departments and the District of Columbia. The survey's combined landline and cell

phone weighted response rates in 2018 ranged from 67.2% in South Dakota to 38.8% in California, with a median rate of 49.9%. Detailed information about the survey is presented on the BRFSS website.<sup>16</sup>

Men aged 40 years or older were asked "Have you ever had a PSA test?" Those who answered "No" were assigned as never having had the test. Men who answered "Yes" were asked, "How long has it been since you had your last PSA test?" Men who reported having had the test within the past year were further asked "What was the main reason you had this PSA test?" Answers included the following choices: "as part of a routine examination"; "because of a prostate problem," "because of a family history of prostate cancer," "because you were told you had prostate cancer," or "some other reason." We examined the outcome of having had PSA test "within the past year (any time less than 12 months)" and included only men who were tested as part of a routine examination to study screening prevalence and be consistent with previous studies.<sup>8,12,17,18</sup> Men who were tested within 1 year for other reasons were excluded from the analysis. We also excluded men who responded "do not know/not sure" (6.8%) and those who refused to answer (1%).

## Statistical Analysis

We used individual-level data with county-of-residence from the 2018 BRFSS restricted data set after adding state and county information to each BRFSS record. Of 130,547 men aged 40 years or older who responded to the question about whether they had ever had a PSA test, a sample of 116,654 men (representing nearly 60.3 million men) was used for our analysis after exclusions. We linked these data to the 2018 American Community Survey 5-year county-level poverty estimates,<sup>19</sup> received from the US Census, to fit multilevel logistic regression models with both fixed and random effects.<sup>20</sup> Fixed effects included 9 age groups (40 to 44, 45 to 49, 50 to 54, 55 to 59, 60 to 64, 65 to 69, 70 to 74, 75 to 79, and  $\geq 80$  years), 7 racial and ethnic groups, (non-Hispanic [NH] white, NH black, NH American Indian/Alaska Native [(AIAN)], NH Asian, NH Pacific Islander, 2 or more races, and Hispanic), and county-level poverty ( $< 150\%$  of the federal poverty rate). We excluded BRFSS respondents coded as "other race"

from our analysis since this category was not part of the US Census data. Random effects were state- and county levels. Our multilevel logistic regression models were fitted with unweighted data using the GLIMMIX procedure, SAS version 9.4 (SAS Institute, Inc., Cary, NC). This approach was justified by 2 validation studies showing the benefits to the estimates' accuracy compared with those of weighted data.<sup>21,22</sup> Some counties' random effects were missing because they did not have any BRFSS respondents available for analysis. To complete the list of random effects for all counties, we generated county-level random effects for these counties with missing data by averaging the neighboring counties' random effects. Further details about the reasons for our choice of the smoothing method are described previously.<sup>23-24</sup> We post-stratified the predicted probability of having a PSA screening test by 197,946 (9 age groups x 7 race/ethnicity groups x 3142 counties) specific geodemographic groups with US Census estimated county population counts<sup>25</sup> and estimated their corresponding standard errors using a Monte Carlo simulation method. The poststratification process adjusts the estimates using a weighted average of estimates from all possible geodemographic combinations ("197,946 cells"). We aggregated these specific geodemographic group prevalence estimates of having had a PSA screening test to generate county-level prevalence estimates and their standard errors for all men aged 40 or older, and for men in each of 3 age groups, including 2 age groups for whom the USPSTF issued recommendations (40 to 54, 55 to 69,  $\geq 70$  years). Further details about our methodology to generate county-level estimates and aggregate them to state and national-level estimates are described in prior studies.<sup>14,20</sup>

We did not present detailed information for age-group 40 to 54 years, for whom no recommendation was made.

Because BRFSS is a state-based surveillance system, we compared our model-based state-specific estimates with their corresponding BRFSS direct (weighted) state estimates and evaluated their internal consistency using the Spearman and Pearson correlation coefficients.

To help the reader identify patterns of PSA screening uptake on a national level, we presented a descriptive table of the unweighted and weighted percentages of PSA screening within 1 year by age, race, and ethnicity groups using the BRFSS 2018

data. The unweighted and weighted percentages reflect findings both in the sample and the study population respectively.

## Results

Our descriptive analysis shows that PSA screening increased with increasing age groups but decreased among men aged 80 years or older. Nationally, men aged 70 to 79 years had the highest weighted percentage of PSA screening at 37.5%. Non-Hispanic White men (22.5%), followed by Non-Hispanic Black men (18.4%), had the highest PSA screening uptakes while Hispanic and non-Hispanic Pacific Islanders had the lowest, at  $<12.0\%$  (Appendix Table 1).

Our county-level findings show that, after post-stratification, our simulation program generated estimates for all 3142 counties in the US. The BRFSS data analysis, using the GLIMMIX procedure, however, had 140 counties where random effects were missing. Most of these counties were in rural areas.

At a national level, the prevalence (mean percent) estimate generated by the model-based SAE for men aged 40 years or older who had a PSA screening test was 20.6% (95% Confidence Interval [CI], 20.2%-21.0%; Table 1). This estimate was slightly higher than the direct 2018 BRFSS prevalence estimate: 19.8%, (95% CI, 19.3%-20.2%), which represented 11,913,307 men. The national SAE county mean estimate was 21.9%, and the estimates varied from 7.9% to 38.1%. National prevalence increased with increasing age-group (7.7%, 27.2%, and 33.7% for men aged 40 to 54, 55 to 69,  $\geq 70$  years, respectively) and were almost the same as the direct BRFSS estimates. Mean county prevalence also increased in higher age groups. The ranges in county prevalence for the 3 age groups were 8.3% for ages 40 to 54 years, 30.0% for ages 55 to 69 years, and 37.1% for ages  $\geq 70$  years.

At the state level, Spearman and Pearson correlation coefficients between the SAE model state-level estimates and the BRFSS direct state estimates were 0.94 for all men aged  $\geq 40$  years, 0.94 and 0.89 for ages 40 to 54 years, 0.89 and 0.92 for ages 55 to 69 years, and 0.86 and 0.85 among men aged  $\geq 70$  years, respectively (Table 2). Overall model-based and BRFSS mean and median states' estimates were similar.

**Table 1. National Estimates From the 2018 Behavioral Risk Factor Surveillance System (BRFSS), and Model-Based PSA Screening Summary Estimates for the Total Population and 3142 Counties, by Age Group\*†**

Age Group, years	BRFSS 2018	Model-based national and county summary statistics						Overall Range
	Mean (95% CI)	Mean (95% CI)	Min	Q1	Median	Q3	Max	
≥40								
US	19.77 (19.31–20.24)	20.59 (20.18–21.00)						
Counties		21.93	7.87	20.00	22.27	24.07	38.14	30.27
40 to 54								
US	7.85 (7.38–8.36)	7.67 (7.43–7.92)						
Counties		7.82	4.33	7.26	7.8	8.32	12.62	8.28
55 to 69								
US	26.72 (25.89–27.56)	27.23 (26.50–27.96)						
Counties		27.75	10.52	25.60	28.05	30.31	40.51	29.99
≥70								
US	33.39 (32.16–34.65)	33.67 (32.64–34.67)						
Counties		34.22	15.60	30.82	34.23	37.61	52.66	37.06

PSA, Prostate-specific antigen; Min, Minimum; Q1, 25<sup>th</sup> percentile; Q3, 75<sup>th</sup> percentile; Max, Maximum; CI, Confidence interval.

\*2018 BRFSS sample size for age ≥40 is 116,654. BRFSS percentages are weighted to the study population.

†Estimates are presented as percentages (%). Model-based results are based on data from the 2018 BRFSS, US Census 2018 American Community Survey 5-year county-level poverty estimates, and the US Census estimated county population counts.

Geographic patterns of PSA screening were similar overall and among men aged 55 to 69 and ≥70 years (Appendix Figure 1a-1c): the largest cluster of states with high prevalence was in the South, Appalachian states, such as Ohio, West Virginia,

and Tennessee, and part of the Midwest. Among men aged ≥40 years, estimated state prevalence ranged from 14.4% in New Mexico to 27.0% in West Virginia (Table 3). The range of county estimates within a state varied from 1.9 percentage

**Table 2. Spearman and Pearson Correlation Coefficients Between Model-Based PSA Screening State-Level Estimates and BRFSS 2018 Direct State Estimates, by Age Group\*†**

Age Group, years	No. of States	Correlation <sup>‡</sup>		Min (%)	Mean (%)	Median (%)	Max (%)
		Spearman <sup>§</sup>	Pearson <sup>  </sup>				
≥40	51	0.94	0.94				
Model-based				14.36	20.71	20.94	27.00
BRFSS				12.18	19.54	19.88	27.52
40 to 54	51	0.94	0.89				
Model-based				4.52	7.68	7.74	10.31
BRFSS				2.65	7.73	7.39	13.77
55 to 69	51	0.89	0.92				
Model-based				17.88	27.13	27.58	32.84
BRFSS				15.26	26.07	25.77	34.56
≥70	51	0.86	0.85				
Model-based				24.40	33.62	33.10	44.18
BRFSS				23.45	33.46	33.51	41.06

PSA, prostate-specific antigen; BRFSS, Behavioral Risk Factor Surveillance System; Min, Minimum; Max, Maximum.

\*BRFSS 2018 sample size for age ≥40 is 116,654. BRFSS percentages used for comparisons with the Model-based are weighted to the study population. The total number of counties in the model-based is 3,142.

†Model-based results are based on data from 2018 BRFSS, US Census 2018 American Community Survey 5-year county-level poverty estimates, and the US Census estimated county population counts.

‡Correlation coefficients between model-based state-level estimates and 2018 BRFSS direct state estimates.

§Spearman correlation coefficient; || Pearson correlation coefficient.

**Table 3. Model-Based SAE State Prevalence Estimate, and County Statistics Summarized by State for PSA Screening Among Men Aged  $\geq 40$  Years, for 50 States, the District of Columbia, and 3142 Counties, 2018**

State	State Mean*	County Summary Statistic*						
		Min	Q1	Mean	Median	Q3	Max	Range <sup>†</sup>
Alabama	24.98	20.03	23.13	24.45	24.53	25.50	30.24	10.21
Alaska	19.14	7.87	13.56	16.57	17.82	19.40	22.39	14.52
Arizona	21.76	10.97	15.92	19.15	19.17	21.81	26.71	15.74
Arkansas	23.12	18.38	21.47	27.67	22.40	23.96	27.33	8.95
California	15.85	11.65	15.01	16.94	16.38	18.84	23.22	11.57
Colorado	17.36	11.56	16.93	18.73	18.86	20.33	24.36	12.80
Connecticut	21.69	18.25	20.68	21.62	22.25	22.81	23.23	4.97
Delaware	24.43	22.00	22.00	25.10	23.75	29.54	29.54	7.54
District of Columbia	17.76			17.76				
Florida	25.61	19.21	22.58	25.38	24.87	27.68	38.14	18.94
Georgia	24.14	17.78	23.22	24.47	24.23	25.63	32.01	14.23
Hawaii	15.64	14.98	15.46	15.83	15.73	16.10	16.88	1.90
Idaho	20.17	15.42	18.74	20.55	20.65	22.16	24.66	9.24
Illinois	19.44	16.30	21.14	22.11	22.09	23.15	25.88	9.57
Indiana	19.43	16.71	18.94	19.78	19.76	20.53	22.79	6.08
Iowa	21.22	16.63	21.23	22.22	22.32	23.14	27.31	10.68
Kansas	22.55	14.46	23.13	23.99	24.43	25.47	29.06	14.60
Kentucky	21.86	16.74	20.84	21.98	22.00	23.11	27.60	10.86
Louisiana	23.81	17.01	21.94	23.02	22.92	24.14	27.21	10.20
Maine	15.84	13.71	14.49	15.93	15.74	16.81	19.21	5.49
Maryland	19.55	16.43	18.21	20.57	19.84	22.96	25.74	9.30
Massachusetts	18.39	16.11	17.78	19.10	18.37	19.68	25.69	9.58
Michigan	20.27	17.20	19.94	21.31	21.16	22.44	26.51	9.31
Minnesota	17.69	14.67	18.09	19.14	19.26	19.99	23.54	8.87
Mississippi	23.53	17.31	22.01	23.02	23.16	24.53	27.75	10.43
Missouri	23.93	19.26	23.00	24.00	24.07	25.12	29.74	10.47
Montana	23.87	15.48	23.02	24.56	25.52	26.73	29.16	13.67
Nebraska	20.12	16.09	21.26	22.64	23.08	24.00	28.83	12.74
Nevada	17.21	15.81	17.20	19.02	18.58	19.52	25.94	10.13
New Hampshire	19.29	15.38	17.04	19.02	19.59	20.02	23.31	7.92
New Jersey	24.20	18.95	23.24	24.63	25.49	26.80	29.03	10.08
New Mexico	14.36	8.37	13.75	14.98	14.69	16.33	20.44	12.07
New York	20.68	14.45	19.03	20.43	20.68	22.03	28.58	14.13
North Carolina	23.66	17.19	22.67	24.17	23.94	25.29	32.34	15.14
North Dakota	21.37	10.70	21.57	22.97	23.79	24.86	27.87	17.17
Ohio	21.97	17.09	21.11	22.28	21.92	23.50	27.88	10.79
Oklahoma	23.32	17.24	22.56	23.33	23.22	24.36	27.18	9.94
Oregon	15.97	13.27	16.23	17.09	17.22	18.46	20.15	6.88
Pennsylvania	21.90	18.76	21.30	22.32	22.38	23.10	25.86	7.10
Rhode Island	20.60	18.53	20.56	22.91	23.25	25.37	26.82	8.29
South Carolina	26.14	20.44	23.16	25.14	24.95	26.17	34.97	14.53
South Dakota	21.73	8.57	19.94	21.37	22.70	24.16	26.06	17.49
Tennessee	23.25	18.99	22.99	23.88	23.90	24.97	30.26	11.23
Texas	18.59	11.22	18.22	20.30	20.60	22.64	29.21	17.99
Utah	16.52	12.43	16.95	18.19	18.61	20.30	23.07	10.64
Vermont	15.02	12.62	13.65	15.15	15.34	16.08	19.14	6.52
Virginia	20.94	15.11	20.41	22.06	22.13	23.67	27.82	12.70

*Continued*



Table 3. Continued

State	State Mean*	County Summary Statistic*						
		Min	Q1	Mean	Median	Q3	Max	Range†
Washington	15.44	13.01	15.52	17.45	17.13	19.92	22.68	9.67
West Virginia	27.00	22.52	25.56	26.79	26.77	27.96	31.79	9.38
Wisconsin	19.56	12.96	19.65	20.49	20.42	21.46	25.03	12.07
Wyoming	24.57	20.86	22.96	24.74	24.56	26.83	29.82	8.96

SAE, small area estimation; PSA, prostate-specific antigen; Min, Minimum; Max, Maximum; Q1, 25<sup>th</sup> percentile; Q3, 75<sup>th</sup> percentile; BRFSS, Behavioral Risk Factor Surveillance System.

\*State prevalence is presented as means and estimates are presented as percentages (%). Model-based results are based on data from the 2018 BRFSS, US Census 2018 American Community Survey 5-year county-level poverty estimates, and the US Census estimated county population counts.

†Range means the difference between the minimum and maximum estimated percentages.

points in Hawaii to 18.9 percentage points in Florida (Table 3).

At both state and county levels, PSA screening prevalence was higher for men aged  $\geq 70$  years compared with men aged 55 to 69 years (Table 4). State prevalence (mean percent) of PSA screening among men aged 55 to 69 years, for whom the USPSTF recommendations emphasized informed decision-making for screening, varied from 17.9% in New Mexico to 32.8% in Delaware (Table 4). County prevalence among the states ranged from a minimum of 10.5% in Alaska to a maximum of  $\geq 40.0\%$  in Alabama, Arkansas, and Florida, with 9 states having a median county prevalence of  $\geq 30.0\%$ . The states' overall county ranges (minimum to maximum) for this age-group varied from 4.7% in Hawaii to 25.1% in South Dakota. States having their 25<sup>th</sup> percentile of county prevalence at 20.6% (the model's national county mean, Table 1) or lower, included Hawaii, Alaska, Washington, Oregon, California, New Mexico, Vermont, New Hampshire, and Maine.

Similar patterns of variation in PSA screening in state and county prevalence estimates were observed among men aged  $\geq 70$  years (Table 4). For these men, 20 states had a prevalence  $\geq 35.0\%$  of which the majority were in the South. Some of these states had their 75<sup>th</sup> percentile of county prevalence at 40.0% or more, including Delaware, West Virginia, North Carolina, South Carolina, Florida, Georgia, Alabama, Mississippi, Oklahoma, and Wyoming. The overall county ranges for men aged  $\geq 70$  years varied from 6.8% in Delaware to 25.4% in South Dakota.

## Discussion

In 2018, we estimated that, on average, 1 in 5 men aged 40 years or older received recent PSA screening. PSA screening increased with age, with the highest prevalence occurring in men aged 70 years or older, similar to previous findings albeit with somewhat different age groups.<sup>8,9,17,26,27</sup> The USPSTF recommendation against screening is longest standing for the oldest men, dating back to 2008 for men aged 75 years or older.<sup>1</sup> Our estimates show that, on average, 1 in 3 men aged 70 years or older had PSA screening in the past year. Using the 2018 BRFSS data, we estimated that more than 3.76 million men aged 70 years or older had routine screening during the past year. During 2012 to 2017, major organizations varied in their recommendations on PSA screening. The USPSTF did not recommend PSA screening, but Medicare continued to reimburse annual PSA screening tests.<sup>28</sup> In 2018, the USPSTF recommended shared decision-making before the initiation of PSA screening. The emphasis on shared decision-making is consistent with current recommendations by the American Cancer Society (ACS)<sup>29</sup> and the American Urologic Association (AUA).<sup>30</sup> We cannot draw conclusions about the relationship between the 2018 USPSTF recommendations and the study results because the implementation of recommendations to clinical practice may require several years, and some providers may follow an older recommendation from other groups.

Our 3 county-level maps revealed a similarity among men aged 55 to 69 and  $\geq 70$  years in areas of high PSA screening prevalence in the United States. Among men aged 40 and over, the largest

number of counties with the highest prevalence was concentrated in the South, in parts of the Appalachian regions, New Jersey, Kansas, Missouri, and Wyoming. Multiple factors may contribute to the high screening in these areas, such as differences in populations by race, the proportion of older men, or geographic differences in provider intensity of screening practice patterns.<sup>31</sup> For example, the average percentage of adults aged 65 years or older in the Appalachian region is higher than the national average (17.6% vs 15.2%, respectively).<sup>32</sup> It is unknown how Medicare annual reimbursement<sup>28</sup> might have contributed to the observed screening patterns. Our findings that, nationally, men aged 70 to 79 years had the highest prevalence of screening, and men aged 80 years and older had a prevalence greater than 23% may suggest reimbursement's influence on screening. Geographic analyses revealed that screening prevalence was highest in the South regardless of age-group. The wide difference in the prevalence of screening among other states in the United States might also indicate the role providers' practice plays in the high prevalence of screening. Differences in provider types across geographic areas and urban and rural communities,<sup>33</sup> in organizations that most frequently influence providers' practices,<sup>34,35</sup> and in patients' preferences could contribute to varying screening use.

Prostate cancer mortality has declined over time.<sup>36</sup> The prevalence of PSA screening has also declined after the 2012 USPSTF recommendations against routine PSA screening in all men. Despite longer standing recommendations against routine screening for older men, similar to previous findings,<sup>8</sup> we found screening prevalence has continued to be higher in men aged 70 or older than among younger men. State-level prevalence was as high as 44.2% for men age 70 and older, and county-level prevalence in the 75<sup>th</sup> percentile reached 48.6%, compared with 32.8% and 35.9% in men aged 55 to 69 years, respectively. States' and counties' overall prevalence ranges were 19.8% and 37% respectively, indicating considerable variation in the screening of older men across communities. Higher screening use among men aged 70 years or older may reflect, in part, physicians' concerns that older men are more likely to be diagnosed with and die from prostate cancer than are younger men,<sup>37-39</sup> and changes in recommendations may not alter attitudes toward PSA screening practices for some

providers.<sup>40</sup> Higher screening prevalence among older men may also reflect men's preferences. In a web-based survey of men aged 40 to 74 years without prior prostate cancer, most men reported not intending to follow the 2012 USPSTF recommendation. Men aged  $\geq 60$  years were somewhat more likely to report this, although the finding for older men did not persist in the adjusted analysis.<sup>41</sup> This same study reported that worry about developing prostate cancer was associated with the intention to not follow the 2012 recommendation. A different study, aimed at identifying sources of prostate cancer decisional regret with a focus on racial disparities, found that despite an increased risk of prostate cancer among African American men, they had higher medical mistrust and concerns about masculinity than non-African American men, which the authors suggested might have contributed to a higher level of decisional regret.<sup>42</sup>

In our study, the PSA screening prevalence among men  $\geq 70$  years suggests potential overuse and deserves attention. The USPSTF, ACS, and AUA indicated that the length of time required to experience any potential prostate cancer mortality benefit is greater than 10 years.<sup>1,29,30</sup> Because a 75-year-old man has an average life expectancy of about 10 years, many men aged 75 years or older would likely not experience a mortality benefit.<sup>43</sup> Similarly, men younger than 75 years, who have chronic health conditions and a life expectancy of fewer than 10 years, are also unlikely to benefit from screening and treatment.<sup>1,29,30</sup> All 3 organizations also raise concerns about potential harms of screening in this age-group, including overdiagnosis of low-risk cases that would not affect life expectancy and treatment-related harms.<sup>4</sup> These organizations concluded that for men aged  $\geq 70$  years, benefits would not outweigh potential harms and, therefore, have not recommended screening for this group.

The high PSA screening prevalence estimates in some states and counties among men 55 to 69 years suggest a need for a heightened provider and patient awareness about understanding the benefits and risks of screening, and patients' values and preferences of screening. Large variations in PSA screening among states and counties for men age 55 to 69 years were present. Nationally, screening prevalence was estimated to be 27% in this age-group, with a range of state prevalence estimates of 15%, and county prevalence estimates of 30%.

**Table 4. Model-Based SAE State Prevalence Estimate and County Statistics Summarized by State for PSA Screening among Men Aged 55 to 69 Years and ≥70 Years for 50 States, the District of Columbia, and 3142 Counties, 2018**

State	State Mean <sup>‡</sup>	55 to 69 Years *						≥70 Years**								
		County Summary Statistic <sup>‡</sup>						County Summary Statistic <sup>‡</sup>								
		Min	Q1	Mean	Median	Q3	Max	Range <sup>\$</sup>	State Mean	Min	Q1	Mean	Median	Q3 <sup>  </sup>	Max	Range <sup>\$</sup>
Alabama	31.05	22.31	27.83	29.90	29.77	31.72	40.47	18.15	40.73	31.97	36.09	39.20	39.20	<b>41.86</b>	52.37	20.40
Alaska	25.32	10.52	19.16	22.03	22.49	26.45	28.79	18.27	33.32	18.14	24.37	28.45	28.75	31.96	40.36	22.22
Arizona	27.42	14.07	21.58	24.08	23.81	27.90	32.07	18.01	35.76	17.94	25.58	29.03	29.96	32.33	40.45	22.51
Arkansas	31.13	24.10	27.36	29.03	28.90	30.31	40.51	16.41	35.05	27.86	31.93	33.82	33.38	35.56	45.15	17.29
California	21.98	15.39	20.45	22.16	22.04	24.01	29.10	13.71	28.47	20.60	26.81	27.94	28.33	29.53	34.57	13.97
Colorado	25.63	17.51	23.93	25.41	25.62	27.21	32.52	15.01	28.65	22.23	27.30	29.70	29.64	31.97	36.03	13.80
Connecticut	27.19	20.38	25.25	26.60	27.74	28.37	29.72	9.34	34.02	30.50	32.46	33.89	33.25	34.96	39.33	8.83
Delaware	32.84	27.89	27.89	32.15	32.64	35.92	35.92	8.03	37.19	34.15	34.15	38.11	39.29	<b>40.91</b>	40.91	6.77
District of Columbia	23.24			23.24					30.20			30.20				
Florida	31.10	23.43	27.51	30.30	30.15	32.58	40.45	17.02	39.76	30.65	36.07	39.39	39.34	<b>42.46</b>	48.43	17.78
Georgia	31.56	24.35	28.00	30.02	29.78	31.41	39.21	14.86	39.80	31.20	37.02	39.00	38.98	<b>40.61</b>	48.06	16.86
Hawaii	18.94	18.29	18.86	20.64	20.38	22.69	23.01	4.72	31.68	18.89	24.59	26.99	28.28	29.09	34.10	15.21
Idaho	28.48	22.60	25.53	27.40	27.35	28.79	31.43	8.82	30.96	25.31	29.17	31.09	31.42	33.25	36.74	11.44
Illinois	25.94	22.05	27.48	28.59	28.58	29.38	33.03	10.99	29.61	23.96	32.13	33.01	33.08	34.25	36.44	12.48
Indiana	26.83	22.19	25.83	27.09	26.87	28.09	32.93	10.74	30.53	24.78	28.64	30.11	29.81	31.50	38.81	14.03
Iowa	29.43	24.44	28.30	29.41	29.40	30.77	36.83	12.38	31.38	24.88	29.81	31.53	31.35	32.91	40.97	16.09
Kansas	29.70	21.65	28.83	30.31	30.51	31.67	38.46	16.82	36.25	23.66	33.34	35.06	34.72	36.75	45.32	21.66
Kentucky	29.03	23.56	26.91	28.70	28.39	30.23	36.19	12.62	37.14	27.51	35.61	37.59	37.56	39.00	46.00	18.49
Louisiana	30.75	22.72	27.73	29.68	29.24	31.46	37.92	15.19	35.82	29.12	32.84	34.62	34.51	36.08	43.81	14.69
Maine	21.64	15.84	19.03	22.09	22.13	25.01	29.07	13.23	24.68	18.79	21.37	23.55	23.44	25.67	28.88	10.09
Maryland	26.16	20.65	25.34	27.01	26.52	29.56	33.52	12.84	32.87	25.41	30.51	32.66	32.64	34.48	41.20	15.79
Massachusetts	25.82	21.91	23.86	26.26	26.11	28.66	31.32	9.41	27.02	21.51	25.84	27.75	27.87	29.75	34.57	13.06
Michigan	26.91	19.75	26.04	27.56	27.59	28.95	34.13	14.39	32.22	24.85	30.09	31.89	31.35	33.54	40.49	15.64
Minnesota	24.05	19.46	23.62	25.19	25.20	26.54	31.81	12.35	29.49	22.9	28.12	30.25	30.41	31.87	38.10	15.20
Mississippi	27.74	19.24	24.53	26.39	26.46	28.59	35.32	16.09	41.23	32.61	37.96	40.36	40.02	<b>42.58</b>	47.07	14.46
Missouri	30.10	23.63	27.53	28.86	28.77	30.28	34.82	11.19	37.79	30.56	36.09	38.00	37.74	39.47	45.93	15.37
Montana	31.08	21.07	28.74	30.33	30.95	32.25	37.13	16.06	35.85	25.96	33.55	35.78	36.37	37.52	45.39	19.44
Nebraska	26.03	18.79	26.59	28.12	28.01	30.32	35.78	16.99	33.09	24.96	30.73	32.92	32.58	35.22	39.37	14.41

*Continued*



Table 4. Continued

State	55 to 69 Years *										≥70 Years**						
	State Mean <sup>‡</sup>	County Summary Statistic <sup>‡</sup>							County Summary Statistic <sup>‡</sup>								
		Min	Q1	Mean	Median	Q3	Max	Range <sup>§</sup>	State Mean	Min	Q1	Mean	Median	Q3 <sup>  </sup>	Max	Range <sup>§</sup>	
Nevada	23.60	20.79	23.69	24.79	24.28	25.47	31.55	10.77	30.79	23.00	27.40	28.71	28.60	29.96	35.97	12.97	
New Hampshire	24.09	18.63	20.24	23.39	12.73	25.81	27.66	9.03	33.97	24.15	30.11	32.33	33.03	35.32	37.65	13.50	
New Jersey	30.56	23.27	27.17	30.96	31.52	35.34	38.28	15.00	38.49	33.09	37.53	38.84	38.98	<b>40.89</b>	45.03	11.94	
New Mexico	17.88	11.36	17.08	18.85	18.37	20.59	26.26	14.90	24.74	15.5	20.55	22.76	22.55	24.88	29.70	14.09	
New York	27.58	16.24	24.08	26.73	25.91	29.85	35.79	19.55	31.92	21.9	27.75	31.03	30.52	34.23	43.95	22.05	
North Carolina	30.48	20.74	27.86	29.82	29.70	31.75	38.02	17.28	38.83	31.51	36.08	38.00	37.72	<b>48.58</b>	50.47	18.96	
North Dakota	29.47	15.83	28.19	29.63	29.74	31.69	35.01	19.18	30.80	21.66	29.24	31.70	31.57	33.64	39.12	17.47	
Ohio	28.74	22.07	27.09	29.06	29.25	30.53	39.00	16.93	34.95	27.23	32.60	35.20	34.83	37.34	50.59	23.36	
Oklahoma	27.67	19.36	24.50	26.33	26.01	28.14	31.84	12.49	40.13	33.17	37.35	39.66	39.57	<b>41.37</b>	50.38	17.21	
Oregon	21.42	17.42	20.46	21.23	21.36	22.19	26.62	9.20	29.78	25.68	28.13	29.78	29.43	31.18	36.94	11.26	
Pennsylvania	31.93	26.56	30.52	31.92	31.46	33.42	37.72	11.16	30.37	25.89	28.84	30.43	30.20	31.90	37.49	11.60	
Rhode Island	27.04	24.62	26.27	29.64	31.21	32.33	33.78	9.16	31.68	28.81	29.67	34.51	34.81	35.00	44.26	15.45	
South Carolina	32.41	24.12	28.35	30.40	29.37	33.04	38.63	12.77	39.85	30.94	34.16	37.51	37.22	<b>40.46</b>	49.43	18.50	
South Dakota	27.88	12.20	24.60	26.75	28.32	29.87	37.29	25.08	34.63	19.18	31.37	32.63	33.38	35.02	44.57	25.39	
Tennessee	29.74	23.02	28.61	30.14	30.06	31.32	37.65	14.63	37.81	31.10	36.21	37.74	37.67	39.14	45.02	13.93	
Texas	25.67	14.96	23.55	25.07	25.46	27.12	32.78	17.83	33.10	21.32	31.48	32.93	33.59	35.15	45.19	23.87	
Utah	25.22	17.75	23.56	25.15	25.39	26.75	32.72	14.97	29.85	23.93	28.46	30.29	29.94	32.11	39.82	15.89	
Vermont	18.79	15.45	16.68	18.98	19.50	20.37	24.83	9.38	24.40	17.99	21.35	23.99	23.10	27.95	29.08	11.09	
Virginia	28.62	22.58	26.96	28.90	28.90	30.71	35.76	13.18	35.54	27.67	33.59	35.56	35.25	37.50	45.75	18.08	
Washington	19.87	15.98	18.51	20.33	20.11	21.76	26.87	10.89	28.73	23.42	27.58	30.41	29.60	34.60	40.05	16.62	
West Virginia	31.91	25.84	29.62	31.51	31.70	33.73	39.52	13.68	44.18	36.56	40.59	42.94	42.51	<b>44.89</b>	52.66	16.10	
Wisconsin	26.45	15.73	26.14	27.08	27.16	28.5	33.47	17.74	30.06	23.46	28.56	29.93	29.54	31.73	34.85	11.38	
Wyoming	29.44	22.28	27.30	29.37	29.50	32.21	35.69	13.41	39.53	33.73	35.10	38.25	37.77	<b>40.47</b>	46.94	13.21	

SAE, small area estimation; PSA, Prostate-specific antigen; Min, Minimum; Max, Maximum; Q1, 25<sup>th</sup> percentile; Q3, 75<sup>th</sup> percentile; BRFSS, Behavioral Risk Factor Surveillance System.

\*The age group for which the USPSTF recommendations suggest that benefits might exist after discussion with a health care provider.

†This age group is not recommended by the USPSTF for routine PSA screening after discussion with a health care provider.

‡State prevalence is presented as means and estimates are presented as percentages (%).

§Range means the difference between the minimum and maximum estimated percentages.

|| Bold percentages in the 75<sup>th</sup> percentiles are ≥40.0%.

¶Model-based results are based on data from the 2018 BRFSS, US Census 2018 American Community Survey 5-year county-level poverty estimates, and the US Census estimated county population counts.

Because estimates are based on 2018 data about PSA screening in the prior year, the 2012 USPSTF recommendation against routine screening applied to this age-group as well. In 2018, USPSTF concluded that screening decisions should be based on men's expressed preferences after they are informed and understand potential benefits and harms.<sup>4</sup> Thus, estimates provide a baseline for future monitoring of PSA screening after the 2018 USPSTF recommendation.

### Limitations and Strengths

There are several limitations to our study. First, we used cross-sectional data, which does not determine cause and effect relationships between the outcomes and the covariates. Second, the PSA screening data are based on participant self-reports and were not validated with medical records information. Third, we do not know whether informed decision-making has affected screening because of insufficient data. Lastly, the US Census estimated county population count data did not include the category "Other race" as part of the race variable. Therefore, we excluded respondents in this race group from our BRFSS analysis. Nevertheless, our multilevel regression and poststratification approach has been previously validated internally and externally for county-level estimates.<sup>21,22</sup> More research of spatial structure effects on SAE estimation is warranted to reduce bias and increase the precision of these estimates.

Despite these limitations, our study provided county-level estimates from the most recently available data for all the counties in the United States. Our models' estimates, when aggregated, were consistent with reliable direct BRFSS state estimates. A 2016 study comparing individual-level estimates with area-level SAE estimators showed that individual-level, multilevel models consistently performed better for SAE estimation than area-level estimators.<sup>44</sup>

In conclusion, by using an individual-level multilevel estimation method with multiple data sources, we were able to generate estimates for all the counties in the United States, including those without or insufficient sample size for a stable analysis of BRFSS data. The respective national prevalence model-based estimates of the 4 age groups were very similar to the direct BRFSS estimates. We found large variations in PSA screening prevalence within many states. We observed an increased frequency of screening as age

increased, and, inconsistent with all prostate cancer screening recommendations, men aged  $\geq 70$  years had the highest screening prevalence. Our analysis identified areas in which potential overuse of PSA screening among older men may be prevalent. In addition, our analysis identified similar geographic patterns of PSA screening in men aged 55 years and older, raising questions about whether health care providers who are "PSA screeners" in older men may be more likely to screen younger men. Further research is warranted to understand the reasons for the screening prevalence we observed, as well as monitor screening use after the 2018 current recommendations. Interventions leading to informed decision-making among men about prostate cancer screening<sup>45</sup> and more knowledge about clinicians' practices may help improve screening practices and reduce potential screening overuse in areas of high PSA uptake.

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**Appendix Table 1. Unweighted and Weighted Percentages of PSA Screening Within One Year by Age and Race and Ethnicity Groups, BRFSS 2018, (n = 116,654)\*†**

Age Group, years	Sample Size	Unweighted %‡	Weighted % (95% CI)
40 to 49	22,561	4.32	4.51 (4.04-5.03)
50 to 59	29,595	16.90	16.81 (15.98-17.68)
60 to 69	33,718	30.79	30.30 (29.25-31.36)
70 to 79	21,449	37.28	37.50 (35.96-39.05)
≥80	9,331	23.50	23.38 (21.48-25.39)
Race and ethnicity			
NH white	92,133	24.43	22.26 (21.75-22.78)
NH black	8,044	21.12	18.40 (17.01-19.87)
NH AIAN	2,009	12.10	12.46 (9.42-16.31)
NH Asian	2,076	14.45	12.26 (9.72-15.33)
NH PI	369	10.57	11.48 (7.11-18.00)
NH ≥2 races	2,024	15.12	15.02 (12.79-19.40)
Hispanic	6,572	11.41	11.65 (10.04-13.48)

BRFSS, Behavioral Risk Factor Surveillance System; PSA, Prostate-Specific Antigen; CI, Confidence interval; NH, Non-Hispanic; AIAN, American Indian Alaska Native; PI, Pacific Islander.

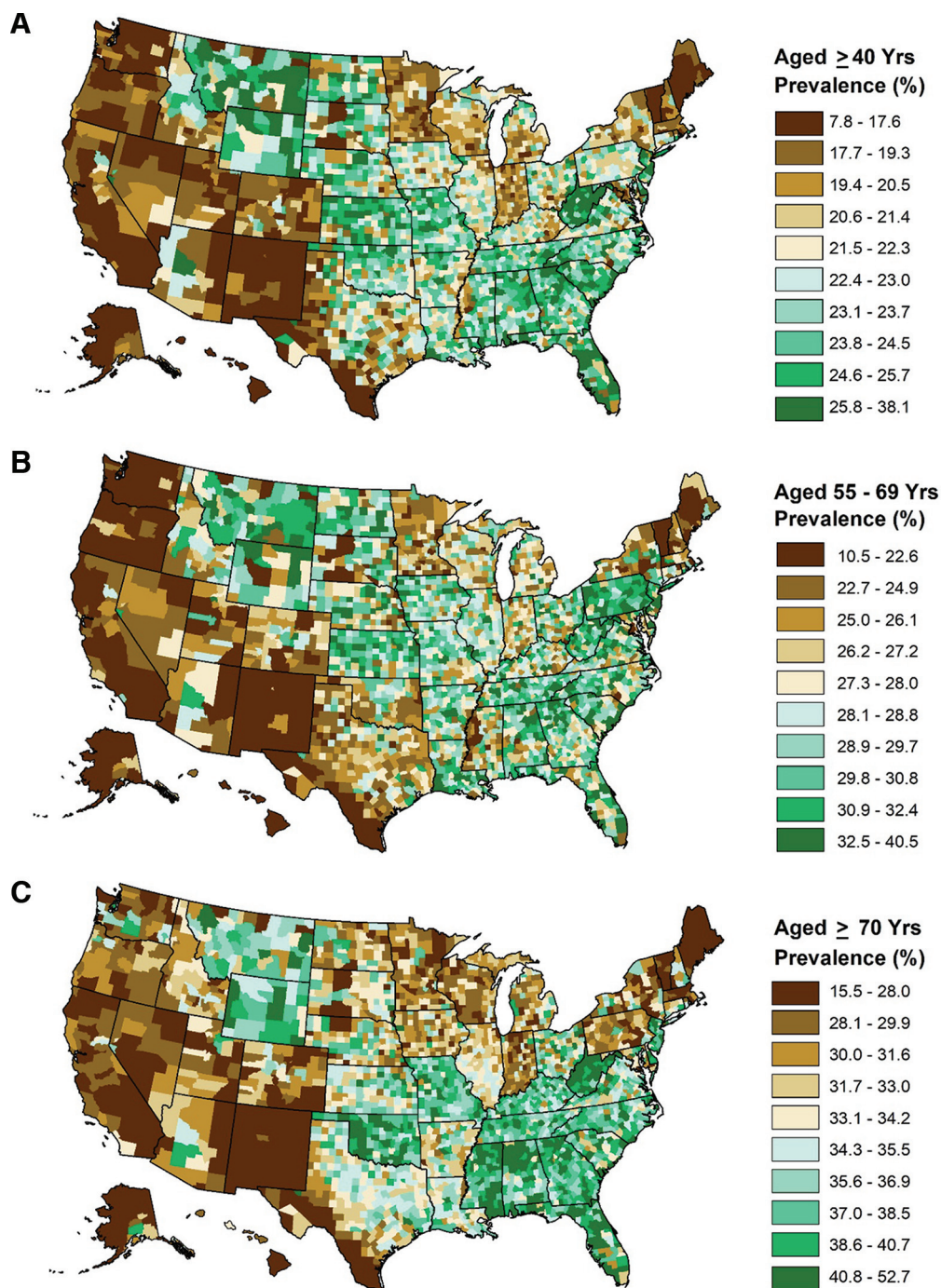
\*We excluded the NH other race group in our analysis to match the US Census race and ethnicity categorization, which we used in our simulation models.

†Sample size is the number of men who answered the question whether they had had a PSA test in the past year (Yes/No or never).

‡An unweighted percentage is the percentage of men reporting having had a PSA screening test within 1 year of the interview in a specific age or race and ethnicity group category. Weighted percentage is an estimate of the prevalence of having had a PSA screening test in the past year in a specific age or race and ethnicity group in the study population.



**Appendix Figure 1. Model-Based Estimated County Prevalence Maps for Men with Prostate-Specific Antigen (PSA) Screening as Part of a Routine Examination Within the Past Year, By Age-Group, Using 2018 Data. Abbreviation: BRFSS, Behavioral Risk Factor Surveillance System.**



**Note:** The county prevalence shown on the right of each map describes the prevalence by deciles, with each associated with a different color scale. Prevalence is presented as a percentage (%). Model-based results are based on data from the 2018 BRFSS, US Census 2018 American Community Survey 5-year county level poverty estimates, and the 2018 US Census estimated county population counts.