American Journal of Men's Health
May-June 1–12

DOI: 10.1177/15579883211026515
journals.sagepub.com/home/jmh
SAGE

Nonlinear Relationship Between Age and Likelihood of Undergoing Prostate-Specific Antigen Testing, and the Predictive Factors of Testing at Different Ages

Hairong He, MS[1,2], Tianjie Liu, MS[3], Fanfan Zhao, MS[2], Xiaojie Feng, MS[2], Jun Lyu, MD, PhD[2,4], and Ye Gao, MD, PhD[5]

Abstract

Objective: To investigate the nonlinear relationship between age and the likelihood of undergoing prostate-specific antigen (PSA) testing, and the difference of factors influencing the test likelihood among subjects aged 40–54, 55–69, and ≥70 years.

Methods: Data were extracted from the 2018 Behavioral Risk Factor Surveillance System, with the primary outcome defined as receipt of a PSA test within the previous 12 months. Restricted cubic splines were used to assess the relationship between age and the likelihood of undergoing PSA testing. Backward conditional logistic regression analyses were used to identify the predictors of undergoing PSA testing among subjects aged 40–54, 55–69, and ≥70 years.

Results: Finally, 92,177 people were identified. The likelihood of PSA testing increased up to around 71 years old and then decreased rapidly for higher ages, showing a clear nonlinear inverted U-shaped relationship with age ($p < .001$). Insurance status, shared decision-making, whether a recommendation for PSA testing had been accepted, income level, smoking status, and age were the common predictors of testing in the three age groups. However, the predictors differed somewhat among the three groups: being overweight or obese was only positively associated with increased testing among people aged 40–54 and ≥70 years, being retired only greatly impacted the test likelihood among those aged 40–54 years, and the general health status, marital status, and race affected people aged ≥55 years.

Conclusion: The factors influencing PSA screening differ with age, which should be fully considered when screening different target age groups.

Keywords

PSA testing, age, predictors, prostate cancer, BRFSS

Received March 22, 2021; revised May 27, 2021; accepted May 31, 2021

Prostate cancer (PCa) is the one of most common cancers in males, with an estimated 1.3 million PCa incident cases in 2018 (Culp et al., 2020). In the United States, PCa accounted for 21% of all new diagnosed cancers and 10% of cancer-caused deaths among males in 2020 (Siegel et al., 2020). Although PCa screening remains controversial, it is still the main method used to reduce the PCa burden. The main purpose of screening is to detect meaningful clinical indications and apply appropriate clinical interventions as early as possible in order to reduce the incidence and mortality of PCa (Smith et al., 2006). The PSA test is currently the most effective and economical method for PCa screening (Lin et al., 2008), with it reportedly reducing the risk of

[1]Clinical Research Center, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi, People's Republic of China
[2]School of Public Health, Xi'an Jiaotong University Health Science Center, Xi'an, Shaanxi, People's Republic of China
[3]Department of Urology, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi, People's Republic of China
[4]Department of Clinical Research, The First Affiliated Hospital of Jinan University, Guangzhou, Guangdong, People's Republic of China
[5]Department of Emergency, The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi, People's Republic of China

Corresponding Author:

Ye Gao (M.D.,Ph.D.), Department of Emergency, The First Affiliated Hospital of Xi'an Jiaotong University, 277 West Yanta Road,Xi'an, Shaanxi 710061, People's Republic of China.
Email: xiaogaoego@163.com

death from PCa by 21% and the rate of metastatic disease at a diagnosis of PCa by 40% (Buzzoni et al., 2015; Schroder et al., 2014).

Based on a full consideration of the benefits and adverse effects of screening, in 2013 the American Urological Association (AUA) recommended narrowing the screening age range to 55–69 years (Carter et al., 2013), which was consistent with the age range recommended by the U.S. Preventive Services Task Force (Jin, 2018). However, according to the Annual Report of the Behavioral Risk Factor Surveillance System (BRFSS), many people aged 40–54 and ≥70 years routinely receive PSA testing, with a lower proportion of people aged 55–69 years being screened (Nguyen et al., 2020). Based on this, the situation regarding PSA screening appears to be inconsistent, and so it is necessary to investigate the possibility of nonlinear relationships between age and PSA screening likelihood, and the predictors of undergoing PSA test among people of different ages. The results could provide guidelines that would act as a sound basis for decision-makers to efficiently implement mass PSA testing and avoid resource wastage.

The relationship between age (as a continuous variable) and screening probability has not been reported previously. Several studies have investigated the factors influencing the frequency of PSA testing (Bowen et al., 2011; Cooper et al., 2019; Kensler et al., 2020; Li et al., 2015; Nguyen et al., 2020; Sammon et al., 2016, 2018; Scosyrev et al., 2012), with most of them based on BRFSS data. However, these studies either investigated the influencing factors for the general population or a certain factor in different age groups. There has been no large-scale survey of the factors influencing the uptake of PSA screening at different ages.

This study was based on the BRFSS data in 2018, and fully considered factors such as demographics, financial status, mental status, and social support when analyzing the relationship between age and the likelihood of undergoing PSA testing. We also separately analyzed the factors influencing testing among people aged 40–54, 55–69, and ≥70 years. The information obtained in this study will provide direction for the development of future health-care policies aimed at improving PSA screening.

Material and Methods

Study Population

The data used in this study were obtained from the latest 2018 BRFSS (https://www.cdc.gov/brfss/annual_data/annual_2018.html). The study population comprised responders who either had or had not received a PSA test within the previous year, which was identified using the following questions: "have you ever had a PSA test?" and "how long has it been since you had your last PSA test?" Responders who answered "yes" to the first question and "within the past year (anytime less than 12 months ago)" to the second question were identified as having undergone PSA testing within the previous year. Responders were identified as having not received a PSA test in the previous year where those who answered "no" to the first question or gave one of the following responses to the second question: "within the past 2 years (1 year but less than 2 years ago)," "within the past 3 years (2 years but less than 3 years ago)," "within the past 5 years (3 years but less than 5 years ago)" or "5 or more years ago." Since we were studying the general population, we deleted responders who underwent a PSA test because of a prostate problem or family history. These people were identified as responders who answered the question of "what was the main reason that you had this PSA test?" with "because of a prostate problem," "because of a family history of prostate cancer," or "because you were told you had prostate cancer."

Study Variables

The primary outcome variable was undergoing a self-reported PSA test within the previous year. The influencing factors that were planned to be analyzed included age, body mass index (BMI), race, self-reported health status, health insurance status, marital status, employment status, education level, income level, smoking status, binge drinking status, urban/rural status, presence of a depressive disorder, and whether a recommendation for PSA testing had been received. Participants who responded with "don't know" or "refused" for these variables were excluded.

Given that American Cancer Society (ACS), the AUA, and the European Urological Association have strongly emphasized the requirement for shared decision-making (SDM) before ordering a PSA test, we also collected SDM information using following questions: "has a doctor, nurse, or other health professional ever talked with you about the advantages of the prostate-specific antigen or PSA test?" and "has a doctor, nurse, or other health professional ever talked with you about the disadvantages of the PSA test?" The SDM status was divided into four categories: discussed both advantages and disadvantages, only discussed advantages, only discussed disadvantages, and did not discuss advantages or disadvantages of testing.

Ethical approval of this study was waived, and informed consent was unnecessary because the data of BRFSS are anonymous and publicly available.

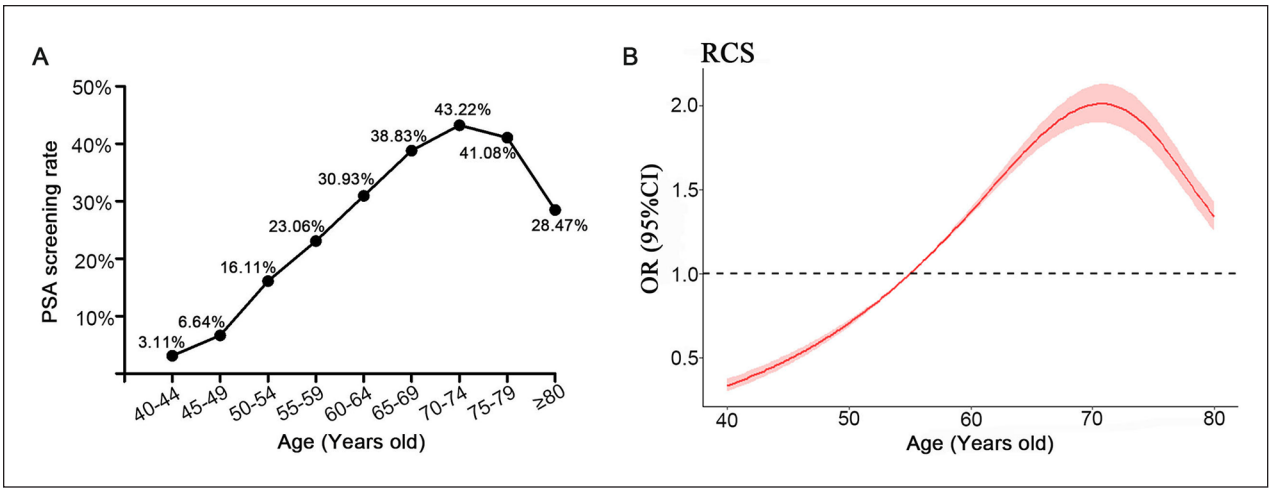

Figure 1. The trend in the likelihood of past-year PSA testing with age (A); adjusted cubic spline models showing association between age and the likelihood of past-year PSA testing (B).

Statistical Analysis

We first drew a line chart to observe the trend in the screening rate for different age groups set by eight 5-year periods from 40 to 79 years plus ≥80 years. Restricted cubic splines (RCSs) were then fitted in adjusted logistic regression models to assess the relationship between age and past-year PSA test likelihood. The adjusted factors included all study variables except for age. The RCS curves had four equally distributed knots, and an age of 55 years was chosen as the reference point for calculating odds ratios (ORs) because this age is the starting age for screening recommended in the most of the guidelines.

Finally, according to the recommended guidelines for screening age, the study population was divided into three groups: 40–54, 55–69, and ≥70 years. We described all variables using count (percentage) values in the three age groups, and analyzed the predictors for undergoing PSA testing in every age group using backward conditional logistic regression while adjusting all of the included study variables.

Results

Relationship Between Age and Past-Year PSA Test Likelihood

The study population comprised 92,177 people. Figure 1A shows the trend in the likelihood of past-year PSA testing with age. At the age of 40–44 years, only 273 (3.11%) persons had undergone a PSA test, and the likelihood of PSA testing increased with age, peaking at 70–74 years of age (4420, 43.22%) and then decreasing for higher ages.

Figure 1B shows the RCSs used in the logistic regression and visualizes the relationship between age (as a continuous variable) and past-year PSA test likelihood. After adjusting all confounding factors (as listed in the Methods), there was a clear inverted U-shaped relationship between age and past-year PSA test likelihood: the likelihood increased up to around 71 years of age and then decreased rapidly for higher ages (p for nonlinearity $<.001$). The test likelihood was lower for those younger than 55 years (OR <1) and higher for those aged ≥55 years (OR >1) compared with that for those aged 55 years.

Distributions of Variables Among Three Age Groups

Based on the recommended PSA screening age in guidelines, we stratified the population into three age groups: 40–54, 55–69, and ≥70 years. Table 1 lists the distribution of possible factors influencing the past-year PSA test likelihood. Most of the entire population was in excellent/very good general health, had health insurance, was married, had a relatively high education level, an income of ≥$50,000, were living in urban areas, white, overweight or obese, had formerly smoked or never smoked, no binge drinking, and no history of depressive disorder.

The proportion of people receiving SDM and a recommendation to undergo a PSA test was much higher in the PSA-test group than in no-PSA-test group. Most of those aged 40–54 years were employed, while most of those aged ≥70 year were retired. The distribution of the urban/rural status did not differ significantly between the PSA-test group and no-PSA-test group among those aged 40–54 years, while the distribution of the variable "ever told

Table 1. The Distribution of Possible Influence Factors of PSA Test Odds for Three Age Groups.

Variables	40–54 years old			50–69 years old			≥70 years old		
	PSA test	No PSA test	*p*	test	No PSA test	*p*	PSA test	No PSA test	*p*
Total	2741	27093		12267	27216		8804	14056	
General health			<.001			<.001			<.001
Excellent/very good	1542(56.26)	14160(52.26)		6543(53.34)	12236(44.96)		4450(50.55)	5809(41.33)	
Good	823(30.03)	8669(32)		3829(31.21)	8732(32.08)		2861(32.5)	4819(34.28)	
Fair/poor	376(13.72)	4264(15.74)		1895(15.45)	6248(22.96)		1493(16.96)	3428(24.39)	
Health insurance			<.001			<.001			<.001
Yes	2620(95.59)	23612(87.15)		11962(97.51)	24969(91.74)		8732(99.18)	13733(97.7)	
No	121(4.41)	3481(12.85)		305(2.49)	2247(8.26)		72(0.82)	323(2.3)	
Marital status			<.001			<.001			<.001
Married/a member of an unmarried couple	1998(72.89)	17844(65.86)		9060(73.86)	16672(61.26)		6194(70.35)	8390(59.69)	
Divorced/widowed/separated	480(17.51)	5416(19.99)		2269(18.5)	7321(26.9)		2253(25.59)	4976(35.4)	
Never married	263(9.6)	3833(14.15)		938(7.65)	3223(11.84)		357(4.05)	690(4.91)	
Education level			<.001			<.001			<.001
Did not graduate High School	102(3.72)	2057(7.59)		382(3.11)	2107(7.74)		347(3.94)	1252(8.91)	
Graduated High School	607(22.15)	7397(27.3)		2745(22.38)	8308(30.53)		1841(20.91)	3691(26.26)	
Attended College or Technical School	698(25.47)	7028(25.94)		3208(26.15)	7332(26.94)		2005(22.77)	3252(23.14)	
Graduated from College or Technical School	1334(48.67)	10611(39.17)		5932(48.36)	9469(34.79)		4611(52.37)	5861(41.7)	
Employment status			<.001			<.001			<.001
Employed	2314(84.42)	23029(85)		6709(54.69)	15238(55.99)		1550(17.61)	2097(14.92)	
Unemployed	91(3.32)	1307(4.82)		281(2.29)	1112(4.09)		50(0.57)	141(1)	
Retired	129(4.71)	493(1.82)		4474(36.47)	7629(28.03)		7074(80.35)	11405(81.14)	
Other	207(7.55)	2264(8.36)		803(6.55)	3237(11.89)		130(1.48)	413(2.94)	
Income level			<.001			<.001			<.001
<$15,000	118(4.3)	1836(6.78)		546(4.45)	2804(10.3)		279(3.17)	997(7.09)	
$15,000–<$25,000	188(6.86)	2985(11.02)		970(7.91)	4151(15.25)		873(9.92)	2510(17.86)	
$25,000–<$35,000	141(5.14)	1906(7.04)		866(7.06)	2543(9.34)		951(10.8)	2007(14.28)	
$35,000–<$50,000	214(7.81)	2911(10.74)		1526(12.44)	3714(13.65)		1450(16.47)	2448(17.42)	
≥$50,000	2080(75.88)	17455(64.43)		8359(68.14)	14004(51.46)		5251(59.64)	6094(43.36)	
Urban/rural			.12			.005			<.001
Urban	2377(86.72)	23201(85.63)		10271(83.73)	22476(82.58)		7404(84.1)	11575(82.35)	
Rural	364(13.28)	3892(14.37)		1996(16.27)	4740(17.42)		1400(15.9)	2481(17.65)	

(continued)

Table 1. (continued)

Variables	40–54 years old			50–69 years old			≥70 years old		
	PSA test	No PSA test	*p*	test	No PSA test	*p*	PSA test	No PSA test	*p*
Race			<.001			<.001			<.001
White, Non-Hispanic	2049(74.75)	20022(73.9)		10543(85.95)	21996(80.82)		7888(89.6)	12189(86.72)	
Black, Non-Hispanic	338(12.33)	2132(7.87)		804(6.55)	1905(7)		413(4.69)	659(4.69)	
Hispanic	186(6.79)	2599(9.59)		348(2.84)	1361(5)		159(1.81)	411(2.92)	
Other	168(6.13)	2340(8.64)		572(4.66)	1954(7.18)		344(3.91)	797(5.67)	
BMI			<.001			<.001			<.001
Normal	417(15.21)	5282(19.5)		2291(18.68)	5806(21.33)		2016(22.9)	3923(27.91)	
Overweight	1191(43.45)	11177(41.25)		5449(44.42)	11459(42.1)		4188(47.57)	6224(44.28)	
Obese	1114(40.64)	10477(38.67)		4469(36.43)	9726(35.74)		2537(28.82)	3761(26.76)	
Underweight	19(0.69)	157(0.58)		58(0.47)	225(0.83)		63(0.72)	148(1.05)	
Smoked			<.001			<.001			<.001
Now smokes every day	224(8.17)	3939(14.54)		925(7.54)	4067(14.94)		310(3.52)	901(6.41)	
Now smokes some days	99(3.61)	1485(5.48)		349(2.85)	1292(4.75)		130(1.48)	304(2.16)	
Former smoker	715(26.09)	6807(25.12)		4553(37.12)	9155(33.64)		4616(52.43)	7356(52.33)	
Never smoked	1703(62.13)	14862(54.86)		6440(52.5)	12702(46.67)		3748(42.57)	5495(39.09)	
Binge drinking			<.001			.004			.04
No	2169(79.13)	20500(75.67)		10530(85.84)	23056(84.71)		8307(94.35)	13170(93.7)	
Yes	572(20.87)	6593(24.33)		1737(14.16)	4156(15.27)		497(5.65)	886(6.3)	
Ever told a depressive disorder			.99			<.001			.75
Yes	393(14.34)	3887(14.35)		1624(13.24)	3972(14.59)		863(9.8)	1396(9.93)	
No	2348(85.66)	23206(85.65)		10643(86.76)	23244(85.41)		7941(90.2)	12660(90.07)	
SDM			<.001			<.001			<.001
Advantage and disadvantage	974(35.53)	2229(8.23)		4436(36.16)	4972(18.27)		2914(33.1)	2982(21.22)	
Only advantage	1240(45.24)	2412(8.9)		6193(50.49)	5424(19.93)		4649(52.81)	3640(25.9)	
Only disadvantage	28(1.02)	224(0.83)		120(0.98)	371(1.36)		115(1.31)	276(1.96)	
Neither	499(18.21)	22228(82.04)		1518(12.37)	16449(60.44)		1126(12.79)	7158(50.92)	
Ever recommended a PSA test			<.001			<.001			<.001
Yes	2242(81.79)	3292(12.15)		10835(88.33)	8542(31.39)		7708(87.55)	5733(40.79)	
No	499(18.21)	23801(87.85)		1432(11.67)	18674(68.61)		1096(12.45)	8323(59.21)	

Note. PSA = prostate-specific antigen; BMI = body mass index; SDM = shared decision-making.

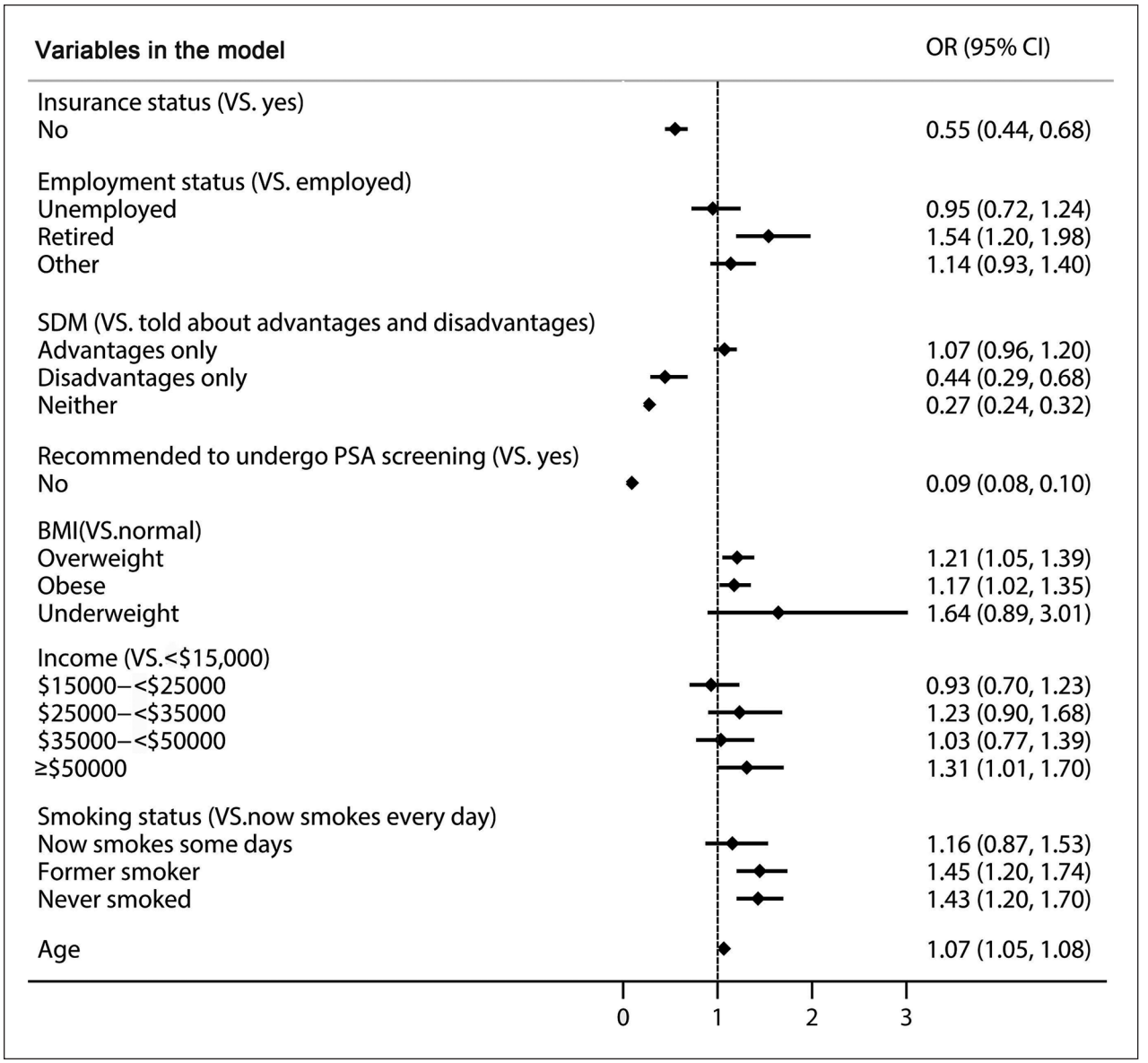

Figure 2. Backward conditional logistic regression analysis of predictors of likelihood of past-year PSA testing in men aged 40–54 years.

a depressive disorder" did not differ significantly between those aged 40–54 years and those aged ≥70 years. The distributions of all of the other variables differed significantly between the PSA-test group and no-PSA-test group for all three age groups ($p < .05$).

Predictors of PSA Test Likelihood for Different Age Groups

We used backward conditional logistic regression to screen for factors affecting the likelihood of PSA testing in the different age groups. Figure 2, Figure 3 and Figure 4 shows the variables that eventually entered the model and their impact on the PSA test likelihood.

Among those aged 40–54 years, the factors that significantly affected the PSA test likelihood were no health insurance (vs. yes: OR = 0.55, 95% confidence interval [CI] = 0.44–0.68, $p < .001$), only discussed the disadvantages of testing (vs. discussed both advantages and disadvantages: OR = 0.44, 95% CI = 0.29–0.68, $p < .001$), did not discuss the advantages or advantages of testing (vs. discussed both advantages and disadvantages: OR = 0.27, 95% CI = 0.24–0.32, $p < .001$, respectively), retired (vs. employed: OR = 1.54, 95% CI = 1.20–1.98,

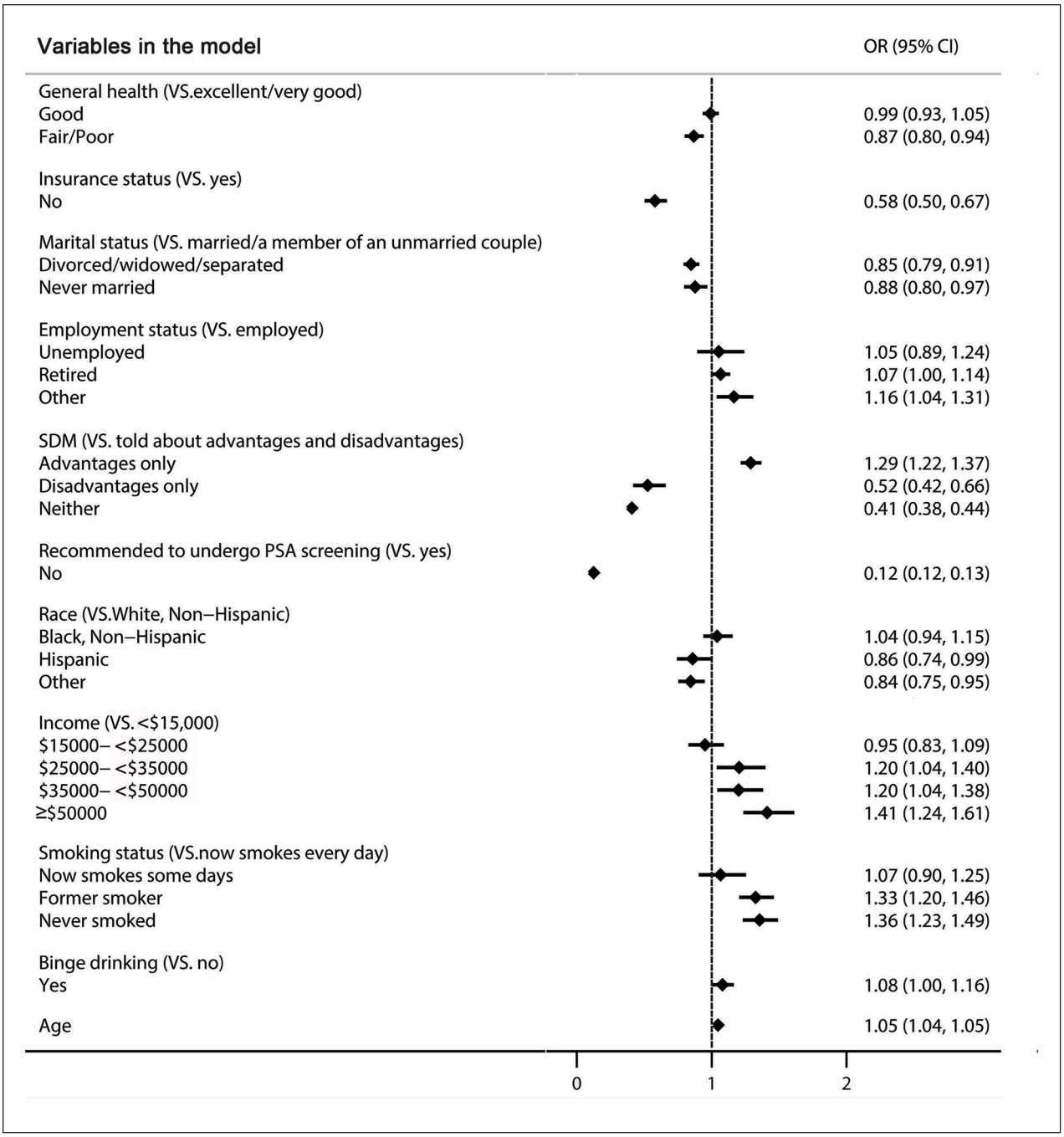

Figure 3. Backward conditional logistic regression analysis of predictors of likelihood of past-year PSA testing in men aged 55–69 years.

$p = .001$), no recommendation about testing (vs. yes: OR = 0.09, 95% CI = 0.08–0.10, $p < .001$), overweight (vs. normal BMI: OR = 1.21, 95% CI = 1.05–1.39, $p = .008$), obese (vs. normal BMI: OR = 1.18, 95% CI = 1.02–1.35, $p = .024$), income of ≥$50,000 (vs. <$15,000: OR = 1.31, 95% CI = 1.01–1.70, $p = .042$), former smoker (vs. current smoker—now smokes every day: OR = 1.45, 95% CI = 1.20–1.74, $p < .001$), never smoked (vs. current smoker—now smokes every day: OR = 1.43, 95% CI = 1.20–1.70, $p < .001$), and age (OR = 1.07, 95% CI = 1.05–1.08, $p < .001$) (Figure 2).

Among those aged 55–69 years, the factors that significantly affected the PSA test likelihood were poor/fair self-reported health (vs. excellent/very good: OR = 0.87,

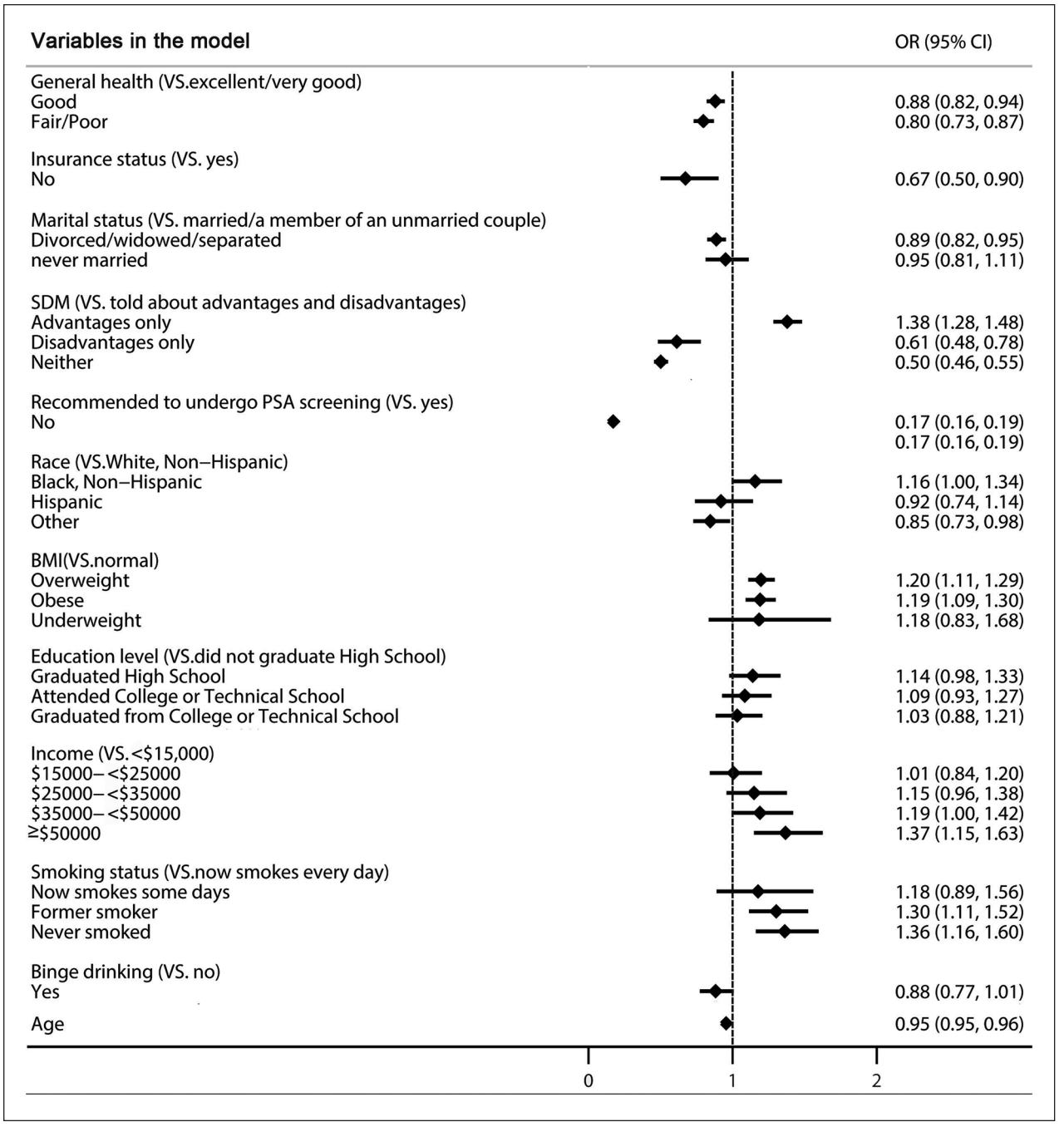

Figure 4. Backward conditional logistic regression analysis of predictors of likelihood of past-year PSA testing in men aged ≥70 years.

95% CI = 0.80–0.94, $p = .001$), no health insurance (vs. yes: OR = 0.58, 95% CI = 0.50–0.67, $p < .001$), divorced/widowed/separated (vs. married married/a member of an unmarried couple: OR = 0.85, 95% CI = 0.79–0.91, $p < .001$), never married (vs. married married/a member of an unmarried couple: OR = 0.88, 95% CI = 0.80–0.97, $p < .001$), only discussed the disadvantages of testing (vs. discussed both advantages and disadvantages: OR = 0.52, 95% CI = 0.42–0.66, $p < .001$), did not discuss the advantages or disadvantages of testing (vs. discussed both advantages and disadvantages: OR = 0.41, 95% CI = 0.38–0.44, $p < .001$), no recommendation about testing (vs. yes: OR = 0.12, 95% CI = 0.12–0.13, $p < .001$), Hispanic (vs. white: OR = 0.86, 95% CI = 0.74–0.99, $p = .038$), other race (vs. white: OR = 0.84, 95% CI = 0.75–0.95, $p = .004$), only

discussed the advantages of testing (vs. discussed both advantages and disadvantages: OR = 1.29, 95% CI = 1.22–1.37, $p < .001$), retired (vs. employed: OR = 1.07, 95% CI = 1.00–1.14, $p = .049$), being a homemaker/a student/unable to work (vs. employed: OR = 1.17, 95% CI = 1.04–1.31, $p = .01$), income of $25,000–<$35,000 (vs. <$15,000: OR = 1.20, 95% CI = 1.04–1.40, $p = .014$), income of $35,000–<$50,000 (vs. <$15,000: OR = 1.20, 95% CI = 1.04–1.38, $p = .011$), income of ≥$50,000 (vs. <$15,000: OR = 1.41, 95% CI = 1.24–1.61, $p < .001$), former smoker (vs. current smoker—now smokes every day: OR = 1.33, 95% CI = 1.20–1.46, $p < .001$), never smoked (vs. current smoker—now smokes every day: OR = 1.36, 95% CI = 1.23–1.49, $p < .001$), binge drinking (vs. no: OR = 1.08, 95% CI = 1.00–1.16, $p = .043$), and age (OR = 1.05, 95% CI = 1.04–1.06, $p < .001$) (Figure 3).

Among those aged ≥70 years, the factors that significantly affected the PSA test likelihood were good self-reported health (vs. excellent/very good: OR = 0.88, 95% CI = 0.82–0.95, $p < .001$), poor/fair self-reported health (vs. excellent/very good: OR = 0.80, 95% CI = 0.73–0.87, $p < .001$), no health insurance (vs. yes: OR = 0.67, 95% CI = 0.50–0.90, $p = .008$), divorced/widowed/separated (versus married married/a member of an unmarried couple: OR = 0.89, 95% CI = 0.82–0.95, $p = .001$), only discussed the disadvantages of testing (vs. discussed both advantages and disadvantages: OR = 0.61, 95% CI = 0.48–0.78, $p < .001$), did not discuss the advantages or disadvantages of testing (vs. discussed both advantages and disadvantages: OR = 0.50, 95% CI = 0.46–0.55, $p < .001$), no recommendation about testing (vs. yes: OR = 0.17, 95% CI = 0.16–0.19, $p < .001$), other race (vs. white: OR = 0.85, 95% CI = 0.73–0.98, $p = .028$), age (OR = 0.96, 95% CI = 0.95–0.96, $p < .001$), only discussed the advantages of testing (vs. discussed both advantages and disadvantages: OR = 1.38, 95% CI = 1.28–1.48, $p < .001$), overweight (vs. normal BMI: OR = 1.20, 95% CI = 1.11–1.29, $p < .001$), obese (vs. normal BMI: OR = 1.19, 95% CI = 1.09–1.30, $p < .001$), income of ≥$50,000 (vs. <$15,000: OR = 1.37, 95% CI = 1.15–1.63, $p < .001$), former smoker (vs. current smoker, smoking every day: OR = 1.30, 95% CI = 1.11–1.52, $p = .001$), and never smoked (vs. current smoker—now smokes every day: OR = 1.36, 95% CI = 1.16–1.60, $p < .001$) (Figure 4).

Discussion

Age is one of the most controversial issues in PSA screening for PCa. We are not aware of any research into the relationship between age and PSA screening rate, or that has examined the different factors affecting PSA screening rates in different age groups. The present study utilized 2018 BRFSS data to investigate the above two shortcomings. We found a nonlinear relationship between age and PSA testing likelihood, with the PSA testing likelihood increasing with age to peak at 71 years, and then decreasing thereafter. We also found there were some differences in the predictors among the three age groups (40–54, 55–69, and ≥70 years): overweight or obese status was only positively associated with increased odds of testing among people aged 40–54 and ≥70 years; retired people had higher test likelihood only for those aged 40–54 years; the general health status, marital status, and race affected people aged ≥55 years. These results had shed light on the gamut of factors that influence the decision-making process for PSA testing in different age groups. When plan to screen the target age group, the influencing factors of the screening odds of this age group should be fully considered. Conductors should focus on publicity and intervention for those with characteristics related to low odds of screening, so as to narrow the screening—disparities among general population.

Drawing a line chart revealed that the screening probability was highest among those aged 70–74 years, which was consistent with the RCS regression analysis showing an inverted U-shaped relationship between age and likelihood of PSA testing with a peak at about 71 years old. This result is consistent with those of Nguyen et al. (2020), who reported that being aged 70–74 years was associated with the highest probability of PSA testing using 2016 BRFSS data. However, there were some discrepancies with previous research findings. Jerant et al. reported that PSA screening increased up to the age range of 75–79 years based on 2001 BRFSS data (Jerant et al., 2004). This difference is partly due to the conflicting recommendations for PCa screening in guidelines or policies in recent decades (Hoffman et al., 2016). In the early 1990s the AUA and ACS began recommending routine annual PSA screening, while the U.S. Preventive Services Task Force has recommended against routine screening since 2000, and in 2008 specifically against screening males older than 75 years (U.S. Preventive Services Task Force, 2008). These policy-related factors may affect the willingness of elderly subjects to undergo PSA screening.

It should be noted that when we analyzed the factors affecting the screening rates in different age groups, we performed age stratification according to the screening age recommended by the guidelines, rather than according to the results of our RCS analysis. We adopted this approach since we thought it might be of more practical significance to the formulation of guidelines. In addition, among those aged ≥70 years, there is no obvious nonlinear trend between age and screening rate. By constructing regression models, we found that insurance status, SDM, whether a PSA test recommendation had been accepted,

income level, and age were the common predictors of PSA testing in the three age groups. These results are consistent with most previous research results (Li et al., 2015; Nguyen et al., 2020).

We found that PSA screening is less common among current smokers. Smoking status has not been considered in previous studies related to PSA screening, but studies of lung cancer screening have reported similar results, with smokers being less willing to undergo computed tomography screening for lung cancer (Pallin et al., 2012; Silvestri et al., 2007). This phenomenon may be related to the large differences in other demographic sociological factors between smokers and nonsmokers. Smokers are more likely to be less educated, nonwhite, have a lower income, report worse health, and less likely to be able to identify a usual source of health care (Silvestri et al., 2007; Tanner et al., 2013). These factors have been identified to be related to low rates of participation in cancer screening both in our research and other studies (Breen and Kessler, 1994; Demark-Wahnefried et al., 1993; Hoffman-Goetz et al., 1998). Moreover, because smoking is an important risk factor for PCa (Pernar et al., 2018), increasing the screening rate of smokers is of practical significance. However, our findings suggest that there are substantial obstacles to the successful implementation of a mass-screening program for PCa that is aimed at current smokers.

Shared decision making exerted important influence on the odds of PSA screening. People only discussed the disadvantages of testing or discussed neither advantages nor disadvantages of testing have lower odds of testing compared with people discussed both advantages and disadvantages. This is consistent with the research results of most articles (Bowen et al., 2011; Cooper et al., 2019; Li et al., 2015; Nguyen et al., 2020). This indicated shared decision making should be increased, especially for people with high risk of PCa, to improve screening rate.

We also found that the predictors of PSA screening probability differed between age groups. Retired people were more likely to undergo PSA testing only among those aged 40–54 years, which is consistent with the findings of Li et al. (2015) for those older than 40 years. The employment status did not have a large impact in the other two age groups in our study, which we speculated was due to most people older than 70 years being retired, and those aged 55–69 years are more affected by the policy orientation, thereby obscuring any impact of employment. We also found that being overweight or obese had a greater impact on the screening likelihood of people aged 40–54 and ≥70 years. This result is expected given that obesity itself is a risk factor for PCa and other diseases (Pernar et al., 2018; Stefan et al., 2013). These people may have a greater awareness of disease prevention, resulting in a higher screening rate despite them not being within the age range recommended for screening. We also found that general health status, marital status, and race exerted impacts among people aged ≥55 years. These factors are consistent with other studies finding an impact on the probability of PSA screening for those older than 50 years (Nguyen et al., 2020; Scosyrev et al., 2012). Knowledge of these differences will be helpful for improving the decision-making for people of different ages.

Races were widely studied as influence factors for PSA screening. However, results were inconsistent. For general population, some researches concluded black men had higher rates and odds of screening than white men (Cooper et al., 2019; Li et al.,2015), while some didn't find any significant differences (Bowen et al., 2011; Nguyen et al., 2020). For specific age groups, Sammon et al. (2016) reported younger black males (45-59 years old) had higher rates of screening than non-Hispanic white men of a similar age. While, the odds was not significantly different between black and white men for the elderly (≥76 years) (Scosyrev et al., 2012). This study got different results that black men showed higher odds of screening than white men only in age group over 70 years. The may reason for the different results was that PSA testing frequencies varies across races, age groups and year of survey (Kensler et al., 2020). Overall, the risk of PCa in the United States differs markedly between different races, as does the availability of medical healthcare resources (Fiscella and Sanders, 2016; Negoita et al., 2018). Research into the application of PSA screening to different races would therefore be very meaningful, and so follow-up research should aim at comparing the factors affecting PSA screening among different races.

The limitations of this study are mainly related to the limitations of the BRFSS database itself. Firstly, the BRFSS data are self-reported and so are prone to recall bias, especially for the elderly. Secondly, the understanding of problem may differ between responders and investigators, leading to measurement bias. Thirdly, there was a certain sampling bias for 2018 BRFSS data due to differences in the level of economic development in various regions. Those living in low-income rural areas may have a lower probability of being linked because of possibly having less phone access. Fourthly, it is difficult to judge whether the purpose of PSA testing is for screening or diagnosis based on the questionnaire information of BRFSS, because of lack of relevant information. However, despite of above information bias of the database, we included a large population-based sample, and the statistical power is very high. The overall results were therefore reliable.

In conclusion, this study found a nonlinear relation between age and PSA test probability, with the likelihood peaking at the age of 71 years. The differences in the

factors that influence PSA screening in different age groups should be fully considered when screening different target age groups. Additional research is needed into the different predictors for decisions about PSA testing among different races.

Acknowledgments

Thanks the 2018 BRFSS Program for providing high-quality open resources.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by the National Social Science Foundation of China (No.16BGL183) and the Science and Technology Development of Shaanxi Province, China (No.2019SF-140). The funders had no role in the study design, collection, analysis, interpretation or writing of the manuscript.

ORCID iD

Hairong He https://orcid.org/0000-0002-6988-6423

References

Bowen, D. J., Hannon, P. A., Harris, J. R., & Martin, D. P. (2011). Prostate cancer screening and informed decision-making: provider and patient perspectives. *Prostate Cancer and Prostatic Diseases*, *14*(2), 155–161.

Breen, N., & Kessler, L. (1994). Changes in the use of screening mammography: evidence from the 1987 and 1990 National Health Interview Surveys. *American Journal of Public Health*, *84*(1), 62–67.

Buzzoni, C., Auvinen, A., Roobol, M. J., Carlsson, S., Moss, S. M., Puliti, D., de Koning, H. J., Bangma, C. H., Denis, L. J., Kwiatkowski, M., Lujan, M., Nelen, V., Paez, A., Randazzo, M., Rebillard, X., Tammela, T. L., Villers, A., Hugosson, J., Schroder, F. H., & Zappa, M. (2015). Metastatic prostate cancer incidence and prostate-specific antigen testing: new insights from the European randomized study of screening for prostate cancer. *European Urology*, *68*(5), 885–890.

Carter, H. B., Albertsen, P. C., Barry, M. J., Etzioni, R., Freedland, S. J., Greene, K. L., Holmberg, L., Kantoff, P., Konety, B. R., Murad, M. H., Penson, D. F., & Zietman, A. L. (2013). Early detection of prostate cancer: AUA Guideline. *Journal of Urology*, *190*(2), 419–426.

Cooper, D. L., Rollins, L., Slocumb, T., & Rivers, B. M. (2019). Are men making informed decisions according to the prostate-specific antigen test guidelines? Analysis of the 2015 Behavioral Risk Factor Surveillance System. *American Journal of Mens Health*, *13*(2), 1818112731.

Culp, M. B., Soerjomataram, I., Efstathiou, J. A., Bray, F., & Jemal, A. (2020). Recent global patterns in prostate cancer incidence and mortality rates. *European Urology*, *77*(1), 38–52.

Demark-Wahnefried, W., Catoe, K. E., Paskett, E., Robertson, C. N., & Rimer, B. K. (1993). Characteristics of men reporting for prostate cancer screening. *Urology*, *42*(3), 269–274, 274–275.

Fiscella, K., & Sanders, M. R. (2016). Racial and ethnic disparities in the quality of health care. *Annual Review of Public Health*, *37*, 375–394.[iss]

Global Burden of Disease Cancer Collaboration. (2019). Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 29 cancer groups, 1990 to 2017: A systematic analysis for the global burden of disease study. *JAMA Oncology*, *5*(12), 1749–1768.

Hoffman, R. M., Meisner, A. L., Arap, W., Barry, M., Shah, S. K., Zeliadt, S. B., & Wiggins, C. L. (2016). Trends in United States prostate cancer incidence rates by age and stage, 1995–2012. *Cancer Epidemiology Biomarkers & Prevention*, *25*(2), 259–263.

Hoffman-Goetz, L., Breen, N. L., & Meissner, H. (1998). The impact of social class on the use of cancer screening within three racial/ethnic groups in the United States. *Ethnicity & Disease*, *8*(1), 43–51.

Jerant, A. F., Franks, P., Jackson, J. E., & Doescher, M. P. (2004). Age-related disparities in cancer screening: analysis of 2001 Behavioral Risk Factor Surveillance System data. *Annals of Family Medicine*, *2*(5), 481–487.

Jin, J. (2018). Screening for prostate cancer. *JAMA*, *319*(18), 1946.

Kensler, K. H., Pernar, C. H., Mahal, B. A., Nguyen, P. L., Trinh, Q. D., Kibel, A. S., & Rebbeck, T. R. (2020). Racial/ethnic variation in PSA testing and prostate cancer incidence following the 2012 U.S.P.S.T.F. recommendation. *JNCI-Journal of the National Cancer Institute*. [vol iss pag]

Li, J., Zhao, G., & Hall, I. J. (2015). Pre-screening discussions and prostate-specific antigen testing for prostate cancer screening. *American Journal of Preventive Medicine*, *49*(2), 259–263.

Lin, K., Lipsitz, R., Miller, T., & Janakiraman, S. (2008). Benefits and harms of prostate-specific antigen screening for prostate cancer: An evidence update for the U.S. Preventive Services Task Force. *Annals of Internal Medicine*, *149*(3), 192–199.

Negoita, S., Feuer, E. J., Mariotto, A., Cronin, K. A., Petkov, V. I., Hussey, S. K., Benard, V., Henley, S. J., Anderson, R. N., Fedewa, S., Sherman, R. L., Kohler, B. A., Dearmon, B. J., Lake, A. J., Ma, J., Richardson, L. C., Jemal, A., & Penberthy, L. (2018). Annual report to the nation on the status of cancer, part II: Recent changes in prostate cancer trends and disease characteristics. *Cancer*, *124*(13), 2801–2814.

Nguyen, D. D., Trinh, Q. D., Cole, A. P., Kilbridge, K. L., Mahal, B. A., Hayn, M., Hansen, M., Han, P., & Sammon, J. D. (2021). Impact of health literacy on shared decision making for prostate-specific antigen screening in the United States. *Cancer*, *127*(2), 249–256.

Pallin, M., Walsh, S., O'Driscoll, M. F., Murray, C., Cahalane, A., Brown, L., Carter, M., Mitchell, P., McDonnell, T. J., & Butler, M. W. (2012). Overwhelming support among urban Irish COPD patients for lung cancer screening by low-dose CT scan. *Lung*, *190*(6), 621–628.

Pernar, C. H., Ebot, E. M., Wilson, K. M., & Mucci, L. A. (2018). The epidemiology of prostate cancer. *Cold Spring Harbor Perspectives in Medicine*, *8*(12), a030361

Sammon, J. D., Dalela, D., Abdollah, F., Choueiri, T. K., Han, P. K., Hansen, M., Nguyen, P. L., Sood, A., Menon, M., & Trinh, Q. D. (2016). Determinants of prostate specific antigen screening among black men in the United States in the contemporary era. *Journal of Urology*, *195*(4 Pt 1), 913–918.

Sammon, J. D., Serrell, E. C., Karabon, P., Leow, J. J., Abdollah, F., Weissman, J. S., Han, P., Hansen, M., Menon, M., & Trinh, Q. D. (2018). Prostate cancer screening in early medicaid expansion states. *Journal of Urology*, *199*(1), 81–88.

Schroder, F. H., Hugosson, J., Roobol, M. J., Tammela, T. L., Zappa, M., Nelen, V., Kwiatkowski, M., Lujan, M., Maattanen, L., Lilja, H., Denis, L. J., Recker, F., Paez, A., Bangma, C. H., Carlsson, S., Puliti, D., Villers, A., Rebillard, X., Hakama, . . . Auvinen, A. (2014). Screening and prostate cancer mortality: results of the European Randomised Study of Screening for Prostate Cancer (ERSPC) at 13 years of follow-up. *Lancet*, *384*(9959), 2027–2035.

Scosyrev, E., Wu, G., Golijanin, D., & Messing, E. (2012). Prostate-specific antigen testing in older men in the USA: Data from the Behavioral Risk Factor Surveillance System. *BJU International*, *110*(10), 1485–1490.

Siegel, R. L., Miller, K. D., & Jemal, A. (2020). Cancer statistics, 2020. *Ca-a Cancer Journal For Clinicians*, *70*(1), 7–30.

Silvestri, G. A., Nietert, P. J., Zoller, J., Carter, C., & Bradford, D. (2007). Attitudes towards screening for lung cancer among smokers and their non-smoking counterparts. *Thorax*, *62*(2), 126–130.

Smith, R. A., Cokkinides, V., & Eyre, H. J. (2006). American Cancer Society guidelines for the early detection of cancer, 2006. *Ca-a Cancer Journal For Clinicians*, *56*(1), 11–25, 49–50.

Stefan, N., Haring, H. U., Hu, F. B., & Schulze, M. B. (2013). Metabolically healthy obesity: Epidemiology, mechanisms, and clinical implications. *Lancet Diabetes Endocrinology*, *1*(2), 152–162.

Tanner, N. T., Egede, L. E., Shamblin, C., Gebregziabher, M., & Silvestri, G. A. (2013). Attitudes and beliefs toward lung cancer screening among US veterans. *Chest*, *144*(6), 1783–1787.

U.S. Preventive Services Task Force. (2008). Screening for prostate cancer: U.S. Preventive Services Task Force recommendation statement. *Annals of Internal Medicine*, *149*(3), 185–191.