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Association of cigarette use with risk of prostate cancer among US males: a cross-sectional study from NHANES 1999–2020

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Abstract

Background Association of cigarette use with risk of prostate cancer remains unclear. We performed this study to examine whether cigarette use is associated with increased risk of prostate cancer.

Methods This cross-sectional study used data from the 1999 to 2020 National Health and Nutrition Examination Survey (NHANES), a population-based nationally representative survey designed to assess the health and nutritional status of US adults and children. Males were eligible if they were aged ≥ 20 years at the time of participation. Cigarette use (ever use, categorized into former use and current use) was defined as having smoked at least 100 cigarettes in life. Smoking duration, cigarettes smoked per day, and smoking pack-years were calculated in former smokers and current smokers. The primary outcome was self-reported diagnosis of prostate cancer by participants. Logistic regression was used to calculate the adjusted odd ratios (aOR) and 95% CI for the associations of cigarette use with risk of prostate cancer, adjusting for demographic characteristics. Subgroup analyses by age group were conducted. Data were analyzed from June 4 to November 30, 2023.

Results Of the 107 622 participants in 1999–2020 NHANES, 28 170 were included in the analysis. The mean (SD) age of the 28 170 participants was 46.4 (16.4) years, 68.0% were non-Hispanic White. Compared with never smokers, ever (aOR, 2.41 [95% CI, 1.15–5.06]) and former smokers (aOR, 3.56 [95% CI, 1.62–7.85]) had a higher risk of prostate cancer. This higher risk in former (aOR, 3.82 [95% CI, 1.69–8.64]) and ever smokers (aOR, 2.82 [95% CI, 1.27–6.25]) was also found in participants aged 20–59 years. Dose-response analysis showed a positive association between smoking duration (aOR, 1.07 [95% CI, 1.03–1.11]), cigarettes smoked per day (aOR, 1.03 [95% CI, 1.00-1.07]), smoking pack-years (aOR, 1.02 [95% CI, 1.01–1.03]) and risk of prostate cancer in current smokers.

Conclusions This study suggests that cigarette use was associated with an increased risk of prostate cancer in US males, especially among those aged 20–59 years. Further research utilizing prospective study design and modeling family history is needed to confirm the findings.

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Keywords Cigarette use, Prostate cancer, Risk, Cross-sectional, NHANES

Background

Prostate cancer (PCa) is the second most common cancer and the fifth leading cause of cancer death in men, with an estimated 1.4 million new cases and 375 000 deaths in 2020 worldwide [1]. Age, race, family history, and germline mutations (e.g., BRCA2, HOXB13, and CHEK2) are well-established nonmodifiable risk factors for PCa [2, 3]. Modifiable risk factors of PCa, such as environmental exposure, infection, lifestyle, and dietary intake, have also been widely discussed [2, 3]. Smoking is a well-known modifiable cause for cancers of 18 sites, the most common of which are the lung, head and neck, bladder, and esophagus [4]. Several studies have revealed potential biological mechanisms between smoking and PCa carcinogenesis [5, 6]. Smoking can result in increased prostatic inflammation [7], which was reported to be associated with the development of PCa [8, 9]. Smoking can also increase testosterone concentrations [5, 6] and a higher level of testosterone was associated with an increased risk of PCa [10].

However, the epidemiological association between smoking and risk of PCa is still a matter of debate, with inconsistent results across different studies [11–14]. A meta-analysis of 24 cohort studies demonstrated that former smokers had a higher risk of PCa compared to never smokers, and current smokers showed a statistically significant elevated risk of PCa in data stratified by the amount smoked [11]. Results from another study (REDUCE) among men with negative pre-study biopsy found that former and current smoking were not associated with total or low-grade PCa risk but current smoking was associated with an increased risk of high-grade PCa [12]. Islami et al. found that ever smoking was positively associated with PCa risk in studies completed before the prostate-specific antigen (PSA) screening era; in overall analyses, current smoking was negatively associated with the occurrence of incident PCa [13]. A recent pooled study involving 5 Swedish cohorts showed that current smoking as associated with a lower risk of PCa, which was most pronounced for low-risk PCa [14].

In this cross-sectional study, we investigated the association of cigarette use with the risk of PCa using the nationally representative data from the National Health and Nutrition Examination Survey (NHANES), and we specifically focused on the PCa risks across different age groups, which were not explored in previous studies. The findings could contribute to the literature by updating earlier research about cigarette use and PCa risk and help policymakers and healthcare professionals make decisions on smoking management.

Methods

Study population

The NHANES is a population-based repeated survey conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention and designed to assess the health and nutritional status of adults and children in the United States (US). The survey combines both in-home interviews and physical examinations. The in-home interviews include demographic, socioeconomic, dietary, and health-related questions. The physical examinations are performed in a mobile exam center, consisting of medical, dental, and physiological measurements, as well as laboratory tests administered by trained medical personnel. The NHANES uses a complex 4-stage survey design to obtain a nationally representative sample and certain groups (racial and ethnic minority groups, individuals with lower income, etc.) are intentionally oversampled to increase precision for subgroup estimates. Data collection for this program was conducted continuously in 2-year cycles since 1999, with a sample of approximately 5000 persons each year. More details regarding NHANES study procedures can be found on the official website (www.cdc.gov/nchs/nhanes/index.htm).

In this study, we used data of NHANES from 1999 to 2020. Participants were included in the analysis if they were males and aged 20 years or older at the time of participation. This age range was appropriate because target NHANES questions on cancer history provided an age limit of 20–150 years old. The NHANES study has been continuously approved by the National Center for Health Statistics Research Ethics Review Board since 1999. All participants provided written informed consent at enrollment. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines for cross-sectional studies [15].

Assessment of cigarette use

Questions on cigarette use were asked by trained interviewers using the computer-assisted personal interview (CAPI) system. The CAPI system was programmed with built-in consistency checks to reduce data entry errors, and the collected data were reviewed by the NHANES field office staff for accuracy and completeness. Smoking status was assessed by the question “Have you ever smoked at least 100 cigarettes in your lifetime?”. Participants who reported having smoked at least 100 cigarettes in their lifetime were defined as ever smokers; otherwise, they were defined as never smokers. Ever smokers were further asked “If yes, are you still smoking cigarettes currently?”, those who still smoked cigarettes at the time of

investigation were defined as current smokers, and those who had quitted were defined as former smokers. We calculated smoking duration (years) based on participants' age at the time of investigation and questions including "How old were you when you first started to smoke cigarettes fairly regularly?" for current and former smokers and "How long has it been since you quit smoking cigarettes?" for former smokers. Cigarettes smoked per day were assessed by asking "During the past 30 days, about how many cigarettes did you smoke per day?" for current smokers and "At that time (when quitting), about how many cigarettes did you usually smoke per day?" for former smokers. Smoking pack-years were calculated by multiplying packs of cigarettes smoked per day by the years the person has smoked, where packs were equal to the number of cigarettes divided by 20. Data on cigarettes smoked per day and smoking pack-years for current smokers were only available from 2003 to 2020.

Ascertainment of prostate cancer

The primary outcome was self-reported diagnosis of PCa, which was based on the participant's response to the following questions: "Have you ever been told by a doctor or other health professional that you had cancer or a malignancy of any kind?" and "What kind of cancer?".

Assessment of covariates

This study adjusted for several demographic covariates. Age was stratified as 20 to 59 and 60 or more years old. Race was recoded as Hispanic (Mexican American and other Hispanic), non-Hispanic White, non-Hispanic Black, and other races (including American Indian or Alaska Native, Native Hawaiian or Pacific Islander, multiple races or ethnicities, or unknown). Education level was categorized as less than high school, high school or equivalent, some college, and college graduate or above. Marital status was grouped as married/living with partner, widowed/divorced/separated, and never married. Family income was evaluated using the poverty-to-income ratio (PIR, a ratio of family income to poverty level) and categorized into low income (PIR $\leq$ 1), middle income (PIR 1–4), and high income (PIR $\geq$ 4) [16]. Health insurance was assessed by asking "Are you covered by health insurance or some other kind of health care plan?" and grouped as "No" and "Yes". Body mass index (BMI), calculated as weight in kilograms divided by height in meters squared, was categorized as underweight (< 18.5), normal ($\geq$ 18.5 & <25), overweight ($\geq$ 25 & <30), and obesity ($\geq$ 30).

Statistical analysis

Statistical analyses were performed from June 4 to November 30, 2023. Participants' characteristics were described by mean (standard deviation, SD) and frequencies (weighted percentages) and compared by cigarette use using Chi-square test, t test, and one-way analysis of variance as appropriate. Multivariable logistic regression was used to calculate the odds ratio (OR) and 95% confidence interval (CI) for the associations of cigarette use with risk of PCa, adjusting for age, race, education level, marital status, family income, health insurance, and BMI. Interaction of age and cigarette use was explored based on evidence that the risk of PCa varies by age [2, 3]. In addition, we conducted dose-response analyses for the associations of smoking duration (years), cigarettes smoked per day, and smoking pack-years with risk of PCa among former and current smokers respectively. Finally, subgroup analyses were conducted across different groups of age, race, education level, family income, and health insurance.

All analyses were conducted in Stata version 16 (StataCorp). Appropriate sample weights were constructed after combing survey cycles, and we used the Taylor series linearization method to calculate the variance for subpopulations of interest accounting for the complex survey design. All P values were from 2-sided tests and results were deemed statistically significant at $P < 0.05$.

Results

Participant characteristics

Of the 107 622 participants in 1999–2020 NHANES, there were 28 250 males aged 20 years or older; 45 and 35 of these males were excluded due to unavailable data on PCa history and cigarette use. A total of 28 170 participants representing 104 893 498 US males were included in this analysis (Fig. 1). The mean (SD) age of participants was 46.4 (16.4) years (Table 1); 6976 (14.5%) were Hispanic, 12 464 (68.0%) were non-Hispanic White, and 6030 (10.4%) were non-Hispanic Black. Compared to never smokers, more former smokers but fewer current smokers were aged 60 years or older, married/living with partner, overweight and obese, and had health insurance (all $P < 0.05$). More former and current smokers had high school or lower education level and low-middle family income than never smokers (all $P < 0.05$). Fewer former smokers but more current smokers than never smokers were non-Hispanic Black (6.2% vs. 13.6% vs. 11.4%, $P < 0.001$). Comparisons of participants' characteristics between ever smokers and never smokers are shown in Additional file 1.

Associations between cigarette use and risk of prostate cancer

Table 2 shows that compared to never smokers, an increased risk of PCa was found in former smokers (aOR, 3.56 [95% CI, 1.62–7.85]) and ever smokers (aOR, 2.41 [95% CI, 1.15–5.06]) but not in current smokers (aOR, 1.20 [95% CI, 0.44–3.23]), adjusting for age, race,

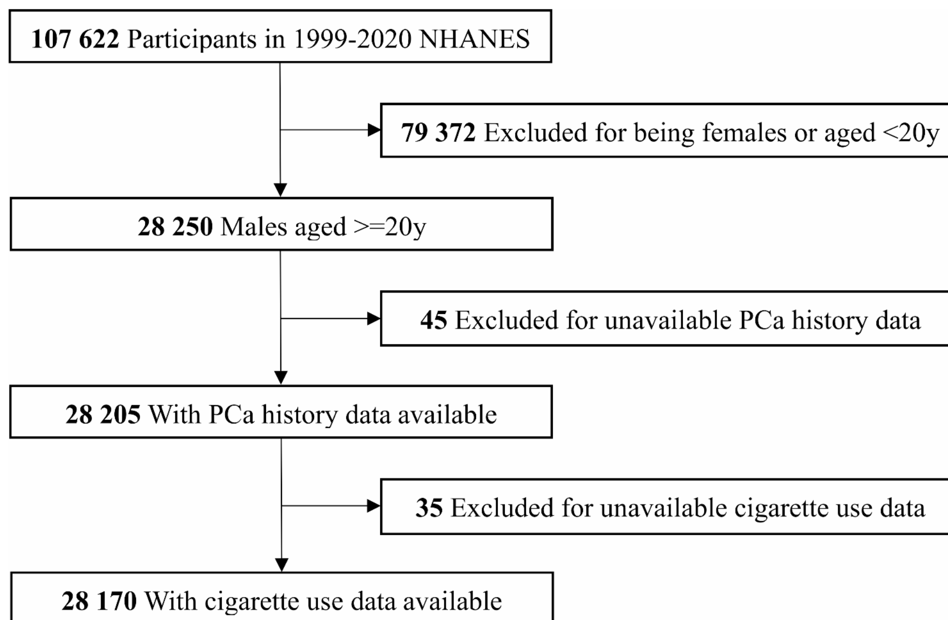

Fig. 1 Study flowchart. NHANES, National Health and Nutrition Examination Survey; PCa, prostate cancer

education level, marital status, family income, health insurance, BMI, and interaction of age and cigarette use. Dose-response analyses showed that longer smoking duration was associated with an increased risk of PCa in current smokers (aOR, 1.07 [95% CI, 1.03–1.11]) but not in former smokers (aOR, 1.00 [95% CI, 0.99–1.02]), adjusting for age, race, education level, marital status, family income, health insurance, and BMI. Similarly, the increased number of cigarettes smoked per day and smoking pack-years were associated with a higher risk of PCa in current smokers (aOR, 1.03 [95% CI, 1.00-1.07]; aOR, 1.02 [95% CI, 1.01–1.03]) but not in former smokers (aOR, 1.02 [95% CI, 1.00-1.04]; aOR, 1.00 [95% CI, 1.00–1.00]).

Table 3 shows that in participants aged 20–59 years, an increased risk of PCa was found in former (aOR, 3.82 [95% CI, 1.69–8.64]) and ever smokers (aOR, 2.82 [95% CI, 1.27–6.25]) but not in current smoker (aOR, 1.49 [95% CI, 0.56–3.97]), adjusting for race, education level, marital status, family income, health insurance, and BMI. In participants aged 60 years or older, current smokers had decreased risks of PCa (aOR, 0.53 [95% CI, 0.32–0.86]) while former smokers (aOR, 0.94 [95% CI, 0.75–1.18]) and ever smokers (aOR, 0.86 [95% CI, 0.69–1.07]) showed neither increased nor decreased PCa risks after adjustment for race, education level, marital status, family income, health insurance, and BMI. Subgroup analyses across varying races, education levels, family income, and health insurance showed that the increased risk of PCa among ever smokers was only evident in participants of non-Hispanic White race (aOR, 4.40 [95% CI, 1.21–16.02]), in participants with education level of some college or above (aOR, 3.55 [95% CI, 1.62–7.79]), in participants with high family income (aOR, 3.05 [95% CI, 1.17–7.90]), and in participants with health insurance (aOR, 2.35 [95% CI, 1.10-5.00]) (Additional file 2).

Discussion

In this study, we firstly explored the associations between cigarette use and PCa risk by including the interaction effect between cigarette use and age. We found a positive association between former and ever cigarette use and PCa risk that persisted after adjustment for age, race, education level, marital status, family income, health insurance, BMI, and interaction of age and cigarette use. Smoking duration, cigarettes smoked per day, and smoking-pack years were positively associated with PCa risk in current smokers. Interestingly, we firstly found the association varies by age groups, with ever and former smokers at an increased PCa risk in men aged 20–59 years but not in men aged ≥ 60 years while current smokers at a decreased PCa risk in men aged ≥ 60 years but not in men aged 20–59 years. Subgroup analyses across different socioeconomic statuses found that ever smokers with high education levels, high family income, and having health insurance were especially more likely to be diagnosed with PCa. Ever smokers of non-Hispanic White race showed an increased PCa risk compared to never smokers.

There are several explanations for these results. Burning cigarettes can produce at least 70 carcinogens, many of which play an important role in PCa carcinogenesis via various biological mechanisms [5, 6]. Our study provided epidemiological evidence on the positive association

Table 1 Baseline characteristics of study participants[a]

Characteristic	Cigarette use, No. (weighted %)				*P* value[b]
	Total (*n* = 28170)	Never (*n* = 12593)	Current (*n* = 6931)	Former (*n* = 8646)	
Age, mean (SD), years	46.4 (16.4)	43.7 (13.4)	41.9 (12.5)	54.2 (14.5)	< 0.001
20–39	9294 (38.7)	5114 (44.5)	2836 (47.7)	1344 (21.9)	< 0.001
40–59	8924 (37.8)	4047 (37.7)	2537 (39.1)	2340 (36.8)	
≥60	9952 (23.5)	3432 (17.8)	1558 (13.2)	4962 (41.2)	
Race					< 0.001
Hispanic	6976 (14.5)	3282 (15.9)	1572 (14.2)	2122 (12.5)	
Non-Hispanic White	12,464 (68.0)	4991 (64.9)	2952 (65.2)	4521 (75.4)	
Non-Hispanic Black	6030 (10.4)	2847 (11.4)	1841 (13.6)	1342 (6.2)	
Other[c]	2700 (7.1)	1473 (7.8)	566 (7.0)	661 (5.9)	
Education level					< 0.001
Less than high school	7848 (17.7)	2800 (12.8)	2477 (26.6)	2571 (18.1)	
High school or equivalent	6727 (25.0)	2642 (21.2)	2016 (32.0)	2069 (25.5)	
Some college	7377 (28.9)	3371 (28.2)	1790 (30.0)	2216 (29.0)	
College graduate or above	6180 (28.4)	3762 (37.8)	639 (11.3)	1779 (27.3)	
Marital status					< 0.001
Married/living with partner	18,137 (67.1)	8157 (68.0)	3762 (56.4)	6218 (74.6)	
Widowed/divorced/separated	4512 (12.8)	1506 (9.3)	1427 (17.6)	1579 (14.5)	
Never married	5267 (20.1)	2831 (22.7)	1664 (26.0)	772 (10.9)	
Family income					< 0.001
Low income	4831 (12.7)	1819 (10.6)	1830 (21.3)	1135 (8.5)	
Middle income	13,565 (48.4)	5776 (44.5)	3398 (54.6)	4435 (50.1)	
High income	7017 (38.9)	3738 (44.9)	1006 (24.1)	2273 (41.4)	
Health insurance					< 0.001
No	6368 (19.9)	2671 (17.0)	2448 (33.5)	1249 (13.4)	
Yes	21,658 (80.1)	9864 (83.0)	4438 (66.5)	7356 (86.6)	
BMI category					< 0.001
Normal	7072 (26.2)	3038 (25.0)	2358 (36.0)	1676 (20.0)	
Overweight	10,117 (38.6)	4548 (39.1)	2239 (34.7)	3330 (41.1)	
Obesity	8645 (34.1)	4025 (35.0)	1695 (27.1)	2925 (39.4)	
Underweight	334 (1.1)	105 (0.9)	179 (2.2)	50 (0.5)	

SD, standard deviation; BMI, body mass index

[a] Accounting for sampling weights

[b] Calculated by Chi-square test or one-way analysis of variance

[c] Other race/ethnicity includes American Indian or Alaska Native, Native Hawaiian or Pacific Islander, multiple races or ethnicities, or unknown

between cigarette use and risk of PCa, which was consistent with several prospective cohort studies [17–19] and high-quality meta-analyses [11, 13]. The REDUCE study found no association between former or current smoking and total PCa risk could probably be due to the short follow-up time of only 4 years as reported, which is not long enough to see the occurrence of PCa [12]. The lower risk of PCa in current smokers can probably be attributed to a lower likelihood of PSA testing compared to non-smokers [6, 13, 14, 20]. Investigational studies have proved that smokers were at risk of PCa but less willing to undergo PSA screen [21, 22] and prostate biopsy [12, 23]. In addition, smokers were reported to have an 8–12% decrease in PSA level compared to never smokers, which may further reduce the possibility of the next-step prostate biopsy [24]. As a result, the detection bias could have attenuated the true association of cigarette use with PCa risk, especially for the low-grade or low-risk PCa that is often asymptomatic [25]. Better socioeconomic status was associated with an increased risk of PCa [26]. Men with better socioeconomic status were more likely to have higher health literacy, better health-related behaviors, and access to healthcare resources [27], therefore were more likely to do PSA testing [22, 28, 29] and prostate biopsy [23]. Current smokers in our study had lower percentages of having a college or above education level and high family income, which may lead to a decreased risk of being diagnosed with PCa. Black men in the US have a nearly 1.8 times higher population-level incidence rate than White men [30]. Determinants of this racial disparity are multifactorial, including socioeconomic and biological factors [31, 32]. Black men were more likely to undergo PSA testing and be referred to urology for PCa compared to White men [33]. We did not find an

Table 2 Association of cigarette use with prostate cancer

Exposures	Diagnosed with prostate cancer, Odds ratio (95% CI)		
	Model 1[b]	Model 2[c]	Model 3[d]
Cigarette use[a]			
Former smokers	2.18 (1.78–2.67)***	3.35 (1.57–7.18)**	3.56 (1.62–7.85)**
Current smokers	0.47 (0.33–0.66)***	1.14 (0.47–2.78)	1.20 (0.44–3.23)
Ever smokers	1.40 (1.15–1.69)**	2.14 (1.07–4.27)*	2.41 (1.15–5.06)*
Smoking duration, years			
Former smokers	1.04 (1.03–1.05)***	1.01 (1.00-1.02)	1.00 (0.99–1.02)
Current smokers	1.11 (1.09–1.13)***	1.06 (1.03–1.09)***	1.07 (1.03–1.11)**
Cigarettes smoked per day			
Former smokers	1.01 (1.00-1.01) *	1.02 (1.00-1.04)	1.02 (1.00-1.04)
Current smokers#	1.02 (1.00-1.04)	1.01 (0.98–1.04)	1.03 (1.00-1.07)*
Smoking pack-years			
Former smokers	1.01 (1.00-1.01) ***	1.00 (1.00–1.00)	1.00 (1.00–1.00)
Current smokers#	1.02 (1.02–1.03) ***	1.01 (1.00-1.02)	1.02 (1.01–1.03)*

OR, odds ratio; CI, confidence interval

Data available from 2003 to 2020

***$P<0.001$, **$P<0.01$, *$P<0.05$

[a] Reference group = never smokers

[b] Crude model

[c] Adjusted for age for "Smoking duration", "Cigarettes smoked per day", and "Smoking pack-years", additionally adjusted for interaction of age and cigarette use for "Cigarette use"

[d] Adjusted for age, race, education level, marital status, family income, health insurance, and body mass index for "Smoking duration", "Cigarettes smoked per day", and "Smoking pack-years"; additionally adjusted for interaction of age and cigarette use for "Cigarette use"

Table 3 Association of cigarette use with prostate cancer by age groups

Exposures[a]	Diagnosed with prostate cancer			
	Crude, OR (95% CI)	*P*	Adjusted OR (95% CI)[b]	*P*
For participants aged 20–59 years				
Former smokers	3.35 (1.57–7.18)	0.002	3.82 (1.69–8.64)	**0.001**
Current smokers	1.14 (0.47–2.78)	0.78	1.49 (0.56–3.97)	0.42
Ever smokers	2.14 (1.07–4.27)	0.03	2.82 (1.27–6.25)	**0.01**
For participants aged 60 years or older				
Former smokers	0.91 (0.74–1.12)	0.36	0.94 (0.75–1.18)	0.59
Current smokers	0.54 (0.35–0.81)	0.004	0.53 (0.32–0.86)	**0.01**
Ever smokers	0.83 (0.68–1.01)	0.07	0.86 (0.69–1.07)	0.17

OR, odds ratio; CI, confidence interval

[a] Reference group = never smokers;

[b] Adjusted for race, education level, marital status, family income, health insurance, and body mass index

increased PCa risk in ever smokers of the Black race or any race other than White, which could probably be due to the small sample size of these races.

Several other reasons are responsible for the lower risk of PCa in elderly current smokers. The US Preventative Services Task Force recommends against PSA-based screening for PCa in men 70 years and older, and for men aged 55–69 years, the decision to undergo periodic PSA-based screening for PCa should be individualized [34]. Furthermore, clinicians may stop testing PSA in individuals with short life expectancy or poor performance status to avoid overdiagnosis and overtreatment due to a high proportion of being indolent PCa in a screening setting [35–37], and the older men are less likely to test PSA and undergo a biopsy on their own initiative [23, 28]. Besides, elderly smokers may die from more aggressive smoking attributable cancers before the diagnosis of PCa. According to the 2022 data from the American Cancer Society [38], lung cancer was the leading cause of cancer death in the US. Approximately 81.7% lung cancer deaths were caused by cigarette smoking directly [39], followed by cancer deaths of larynx (73.8%), esophagus (50.0%), and bladder (46.9%). Heart diseases, chronic lower respiratory diseases, and cerebrovascular diseases were also the most common causes of death in the US [38], and the majority of deaths from these diseases might be attributed to smoking [40]. Recent US cancer statistics [38] indicated that the probability of PCa increases from 1.8% in men aged 50–59 years to 5.1% in men aged 60–69 years, and to 9.0% in men aged 70 years and older, but the prevalence of PCa among the elderly is still vastly underestimated. More than 40% of men > 60 years were identified asymptomatic PCa according to an autopsy series of individuals not screened for PCa and died for causes other than PCa [41], and the proportion increased to 60% in men > 80 years.

The worldwide PCa burden is predicted to grow to almost 2.3 million new cases and 740 000 deaths by 2040 [42]. Although evidence show that PCa incidence and mortality have been on the decline or have stabilized recently in many high-income countries [42], the national economic burden associated with cancer care is still substantial, approximately 3.3 billion dollars in the US according to the 2019 annual report [43]. Cigarette use at PCa diagnosis has showed close associations with aggressive tumor features [5] and higher risks of tumor recurrence, metastasis, and mortality [44, 45], suggesting that it is essential to promote smoking cessation for the benefit of improving prognosis of PCa patients. Our study demonstrated a positive association between cigarette use and PCa risk, and the findings could further emphasize the importance of smoking cessation to prevent the development of PCa. Improving PCa screen in current smokers especially in those with old age and low

socioeconomic status is needed, therefore promoting early diagnosis and treatment of PCa in this population.

Strengths and limitations

Major strengths of this study include the use of nationally representative survey, implement of a series of subgroup analyses, inclusion of interaction between age and cigarette use, and adjustment for potential confounding factors, implying that our findings have great robustness and generalization. This study also has several limitations. First, we cannot avoid the risk of residual confounding by unmeasured covariates as this is a secondary analysis. Specifically, we did not adjust for the family history of PCa due to a lack of data, which may explain the observed findings, further research addressing the influence of family history is warranted. Second, smoking status collected at baseline may change over time, and the use of self-reported questionnaires is subject to recall bias. Future studies should measure cigarette use at multiple time points and consider incorporating medical records to confirm PCa diagnoses. Third, given that most prostate cancers are diagnosed after the age of 55 years [46] and the risk is highest among non-Hispanic Black [2], this study was limited by using a sample with a mean age of 46.4 years and 10% of non-Hispanic Black, which was less representative of the most susceptible population of PCa in the US. Finally, as a cross-sectional study, our findings should be interpreted with caution for inference of causality. The observed greater risk in former smokers could be a reverse causality that being diagnosed with PCa may have promoted smoking cessation.

Conclusions

Our findings suggest that cigarette use was associated with a higher risk of PCa in US males, especially among those aged 20–59 years, and this association was persistent after adjustment for potential confounders. Further research utilizing prospective study design and modeling family history is needed given the cross-sectional design and methodological limitations of our study.

Abbreviations

PCa	Prostate cancer
PSA	Prostate-specific antigen
NHANES	National Health and Nutrition Examination Survey
US	United States
CAPI	Computer-assisted personal interview
PIR	Poverty-to-income ratio
BMI	Body mass index
SD	Standard deviation
OR	Odds ratio
CI	Confidence interval
NA	Not available

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-21863-9.

Supplementary Material 1

Supplementary Material 2

Acknowledgements

Not applicable.

Author contributions

XWY, HC, YSW, and JP conceived the study design and are responsible for the overall content. XWY and HC conducted the data analysis and interpretation. JFZ and SQZ assessed and verified the data. XWY and HC drafted the manuscript, and YSW and JP revised the final article. All authors read and approved the final manuscript.

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Data availability

Data from the National Health and Nutrition Examination Survey (NHANES) 1999-2020 are publicly available online (https://wwwn.cdc.gov/nchs/nhanes/).

Declarations

Ethics approval and consent to participate

This study used data from the National Health and Nutrition Examination Survey (NHANES), which was approved by the National Center for Health Statistics Research Ethics Review Board. All participants provided written informed consent at enrollment.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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