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Prevalence and associated risk factors of prostate cancer among a large Chinese population

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Prostate cancer (PCa) is one of the most important health problems among elderly men in China, with the increasing aging of the population. A cross-sectional survey was conducted in eastern China from 2022 to 2023. Recruitment included a total of 70,342 participants aged 60 or older. Social demographic information, such as individual factors like age, education levels and behavior habits, physical examination and laboratory tests results were collected. Age-standardized prevalence rates were estimated by a direct method with a standard population. T test and chi-square test were used to compare the statistical differences. Multivariate regression models were used to identify the risk factors of PCa. Overall, the crude and age-standardized PCa prevalence is 0.93% and 0.91%, respectively in eastern China. When we adjusted all the co-variables, it showed that high age, smoking, having a higher BMI and higher CA19-9 were associated with a higher risk for a prostate cancer diagnosis. Faced with the demographic transition, innovative strategies are needed to control and prevent PCa. Conducting early screening among male population in community health service centers in eastern of China, especially among a population with associated risk factors such as high age, obesity, and conducting community-based intervention programs might be helpful to address this increasingly significant health problem.

Prostate cancer (PCa) is one of the most common malignant tumors of the urogenital system. According to the Global Cancer Statistics Report published by the WHO International Agency for Research on Cancer (2022), there were 1,466,718 new cases of PCa in the world, ranking fourth after lung cancer, breast cancer and colorectal cancer. PCa deaths were 396,773 cases, the death rate ranked eighth[1]. Recently, the National Cancer Center announced the latest situation of the burden of malignant tumors in China in 2022, among which the incidence cases of PCa is 134,200, ranking ninth among all cancers in China. The standardized incidence was 9.68 ($1/10^5$), ranking sixth among male malignant tumors. 47,500 people died, with a mortality rate of 6.59 ($1/10^5$), ranking seventh among male malignant tumors[2]. Both morbidity and mortality rankings have increased[3]. From a global perspective, the incidence of PCa has obvious geographical and ethnic differences, in Australia/New Zealand, North America and Europe, the incidence is high, with the incidence of more than 85/100,000. The lowest incidence is found in Asia, where the incidence ranges from 4.5 to 10.5/100,000. Although the incidence of PCa in China is much lower than that in Europe and America, it has been increasing year by year in recent years. The main reasons for the increase in the incidence of PCa in China may be aging population, changes in people's lifestyle, and an increased PSA testing activity is also an important reason.

The etiology and pathogenesis of PCa are very complex, and its exact etiology is not clear. Etiological studies have shown that PCa is closely related to genetics, age, exogenous factors (such as environmental factors, dietary habits). Epidemiological data show that the incidence of PCa increases significantly after Asian immigrants to the United States, suggesting that exogenous factors such as geographical environment and dietary habits also affect the incidence of PCa. At present, the exogenous risk factors of PCa are still under study, some factors are still controversial, and there is no clear drug intervention or dietary method to prevent PCa.

The prevalence of PCa is closely related to age, and its incidence increases with age, the older the incidence is higher, and the highest incidence age is 65–80 years old[3]. Zhejiang province, located in eastern China, has an aged population of approximately 12.07 million, accounting for 18.7% of the total population in 2020[4]. There

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is an urgent need to study the prevalence and associated risk factors of PCa, which is lack in eastern China.[5] In this study, we aim to collect and describe PCa prevalence in eastern China. And we also want to identify known risk factors for PCa.

Methods

Population

It was a special health survey sponsored by the government, which aimed to achieve the goal of "early detection, early diagnosis and early treatment" of prostate cancer. The specific goals are to popularize healthy lifestyle, strengthen residents' awareness of active participation in screening, improve self-care awareness, and realize early screening, early diagnosis, early treatment and early rehabilitation of prostate cancer, which in order to improve patients' survival rate and quality of life, and reduce mortality.

This survey was characterized as an observational study of cross-sectional type, using exploratory methods such as surveys and blood collection, carried out in eastern China from June 2022 to August 2023. It was administrated in four communities across 12 counties using the method of multi stage stratified random cluster sampling. First, 12 administrative districts were divided into four type districts based on economic levels. From each of these four groups, one district was systematically selected. Then one community was randomly chosen from each district. Male subjects aged 60 or more living in the selected communities were invited to participate. Inclusion criteria were men who were 60 years or more that lived in selected communities of eastern China, and who willing to undergo PCa screening. The exclusion criteria included of complicated with other malignancies, with history of prostate surgery, severe nervous system diseases or mental diseases, having cognitive disorders and could not complete study assessment independently. 80,063 eligible men resided in the area were recruited, 5965 were excluded because of low compliance. The total sample included a total of 74,098 men, and there was a follow-up after 4 months. After removing the cases with incomplete information, there were 70,342 participants in the final analysis set, including 45,305 in 2022 and 25,037 in 2023. And there were no significant differences among main demographic variables between responders and nonresponders. Flow chart was showed in Fig. 1.

Data collection

Data collection included basic information, physical examinations and laboratory tests. Basic information was collected using a self made questionnaires by trained nurses, which including of individual factors such as age, education levels, marital status, behavior habits such as dietary pattern, exercise habits, alcohol and tobacco consumption information. Physical examination included height, weight, waistline, blood pressure, and heartbeat detection. Laboratory tests included of prostate-specific antigen (PSA), serum carcinoembryonic antigen (CEA), carbohydrate antigen 19 – 9 (CA19-9), fasting blood glucose (FBG), blood lipid level and urine tests.

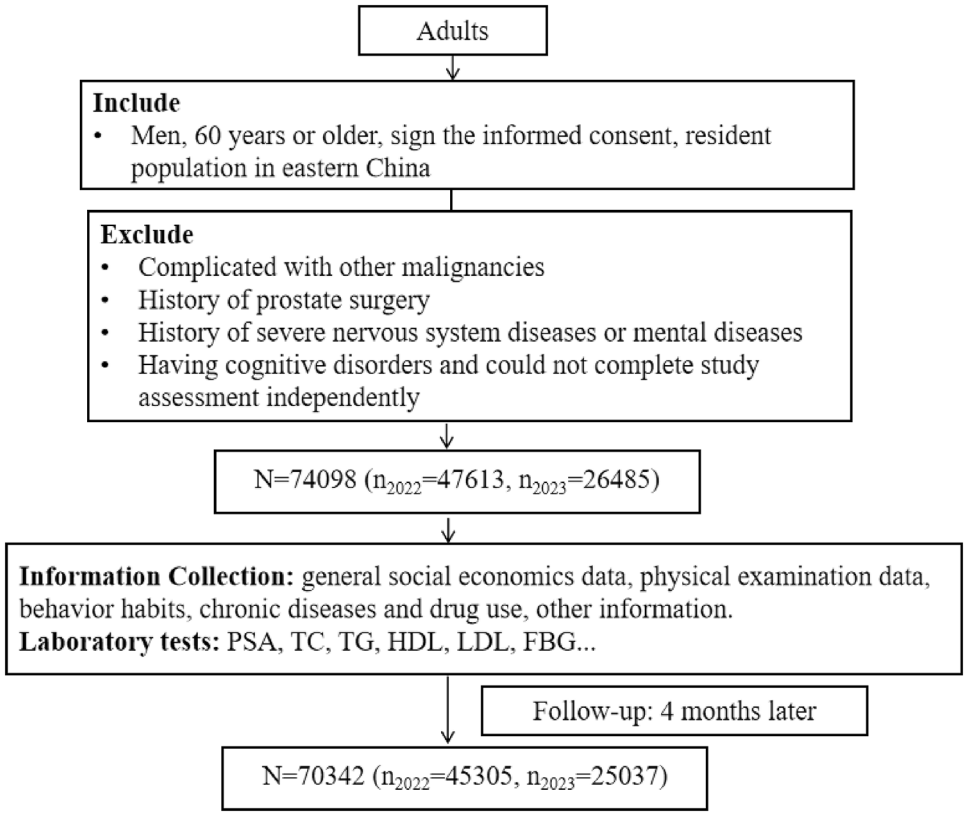

Fig. 1. Flow chart.

Measures

The survey and tests was conducted by trained nurses or general practitioners in community health service centers or participants' residences. Alcohol and tobacco consumption was self-reported by asking questions about the consumption, alcohol consumption was defined as yes if the consumption was at least once a week. Smoking was defined as continuous or cumulative smoking for 6 months or more. Regular exercise was defined as having exercise 3 days a week or more. Hypertension were defined as systolic blood pressure (SBP) equaled to 140 mm Hg or more and/or diastolic blood pressure (DBP) equaled to 90 mmHg or more with BP measured 3 times on diferent days, or having a history of hypertension or taking antihypertensive drugs within 2 weeks[6,7]. Overweight was defined as body mass index (BMI) ≥ 24 kg/m^2 and < 28 kg/m^2, obesity was defined as BMI ≥ 28 kg/m^2[8].

Diabete was defined as fasting plasma glucose (FPG) ≥ 7.0 mmol/L[9]. Dyslipemia was defined as high when one of the indexes of serum triglycerides (TG), serum total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) was abnormal[8]. Serum carcinoembryonic antigen (CEA) was high if CEA ≥ 5 ug/L, alpha fetal protein (AFP) was high if AFP ≥ 9 ng/ml, carbohydrate antigen 19 − 9 (CA19-9) was high if CA19-9 ≥ 39 ug/L.

Blood samples were collected in the morning using vacuum blood collection tubes with 10 mL plastic clot activator with a diameter of 16 × 100 mm. After venipuncture, the blood was stored, to be subsequently centrifuged in pairs for 10 min at 3000 rpm, and stored in an ice box and then transferred to the laboratory that performed the sample processing by immunoassay analyzer[9]. And PSA was measured by Electrochemical luminescence method (Roche Cobas e801, Switzerland). A PSA level equal to or greater than 4 ng/mL was considered high. PSA > 10 ng/mL, any free prostate specific antigen (fPSA)/total prostate specific antigen (tPSA) (f/t PSA) and prostate-specific antigen density (PSAD) values, or PSA 4–10 ng/mL, abnormal f/t PSA value and (or) PSAD value, presence of prostate cancer was further confirmed by core biopsies[3].

Quality control

When measuring height and weight, participants were asked to wear light clothing, no shoes. Blood pressure was measured in a sitting position, resting for at least 5 min before measurement, blood pressure was measured twice on the right upper arm using a standard electronic sphygmomanometer (Omron HEM-7430). If the difference between two readings was greater than 10 mm Hg, a third measurement was taken and the average of the last two readings was used.

The physical examinations were performed at 25 centers. The general project team conducted unified and standardized training for the staff participating in the project in each center. The training introduced the project implementation background, significance and implementation norms. A unified assessment were conducted after training. The staff could participate in the project only after they had passed the exam. The general project team also distributed physical examination tools to each center. All of these measures ensured that the test data of each center did not differ due to operational error. The data in this study based on investigation questionnaire and examinations. And we used a self made questionnaire, which has a high reliability and validity with the Cronbach's α coefficient of 0.83 in this study. In addition, before the survey, a preliminary experiment were carried out to ensure the data accuracy.

Ethics

The study protocol was reviewed and approved by the Institutional Ethics Committee of Zhuji Center for Disease Control and Prevention. The participants were informed about the objectives and methods of the study. They were informed that their participation was totally voluntary and that they could withdraw from the study at any time without citing any reason. Written and signed or thumb printed informed consent was obtained from those who agreed to participate, or from their guardians. All methods used in this research were performed in accordance with the relevant guidelines and regulations.

Statistical analysis

To make the database, the software Epidata (version 3.1) was used, and for the analyses, the statistical software SAS 9.4 was used. The normality of the data was verified by the Kolmogorov-Smirnov test for all analyzed variables. Frequency (percentage) description was used for counting data, and mean and standard deviation description was used for measuring data, so as to study the socio-demographic characteristics. Age-standardised prevalence rates were estimated by a direct method with a standard population (the 7th population census in Zhejiang, 2020). T test and chi-square test were used to compare the statistical differences.

To identify the factors associated with PCa, crude and multivariate regression models were performed with estimates of the odd ratios (OR). The crude models were constructed containing each of the independent variables and the response variable of PCa (yes/no). And the associations were assessed using multivariate models adjusted for the covariates age, education levels, behavior habits and so on. Significance level was set at $p < 0.05$ for all hypothesis tests.

Results

Baseline information

The total sample included 70,342 participants, including 45,305 ones collected in 2022 and 25,037 in 2023, baseline demographics for the study were displayed in Table 1. The median age of the participants was 70 years, and most of them had a education level of primary school or middle school. 32.64% participants had a lifestyle of smoking and 42.53% drinking. The median PSA value was 2.96 ng/ml. More details were showed in Table 1.

Items	Subjects
Age (years), mean ± SD	70.46 ± 6.71
Education levels, No. (%)	
Illiterate	6901 (9.81)
Primary school	39,961 (56.81)
Middle school	18,887 (26.85)
High school or above	4593 (6.53)
Smoker, No. (%)	22,916 (32.64)
Drinker, No. (%)	29,723 (42.53)
High-salt diet, No. (%)	15,977 (22.71)
Meat-based diet, No. (%)	525 (0.75)
High oil diet, No. (%)	394 (0.56)
High-sugar diet, No. (%)	187 (0.27)
Regular exercise, No. (%)	12,381 (17.64)
Waistline (cm), mean ± SD	85.91 ± 8.64
BMI (kg/m3), mean ± SD	23.96 ± 3.15
PSA (ng/mL), mean ± SD	2.96 ± 44.71
PSA, No. (%)	
<4 ng/mL	60,913 (86.6)
4–10 ng/mL	7338 (10.43)
>10 ng/mL	2091 (2.97)
Hypertension, No. (%)	29,498 (41.94)
Diabetes, No. (%)	8068 (11.47)
SBP (mmHg), mean ± SD	137.02 ± 17.53
DBP (mmHg), mean ± SD	80.48 ± 9.85
FBG (mmol/L), mean ± SD	5.82 ± 4.32
TC (mmol/L), mean ± SD	4.75 ± 1.89
TG (mmol/L), mean ± SD	1.52 ± 1.21
HDL (mmol/L), mean ± SD	1.46 ± 0.81
LDL (mmol/L), mean ± SD	2.77 ± 1.51
CEA (ug/L), mean ± SD	3.62 ± 25.32
AFP (IU/mL), mean ± SD	3.52 ± 19.73
CA19-9 (U/ml), mean ± SD	14.55 ± 57.37

Table 1. Participants' characteristics ($n = 70342$). Note: SD, standard deviation; PSA, prostate-specific antigen; SBP, systolic blood pressure; DBP, Diastolic blood pressure; FBG, fasting blood glucose; TC, total cholesterol; TG, triglyceride; HDL, high-density lipoprotein; LDL, low density lipoprotein; CEA, serum carcinoembryonic antigen; AFP, alpha fetal protein; CA19-9, carbohydrate antigen 19 − 9.

Prevalence of of prostate cancer by subgroups

Among the 70,342 cases, there were 655 participants with PCa, the crude prevalence was 0.93%, and the age-standardized prevalence was 0.91%. Table 2 showed the results of the stratification analysis on the main demographic variables. In terms of age, the senior groups (71–80 years, 80 years or more) had higher prevalence. In terms of socioeconomic stratification factors, those who had a habit of smoking or drinking were faced with a higher prevalence.

Associated risk factors of prostate cancer

Table 3 described the associated risk factors of prostate cancer. Logistic regression models including crude model and adjusted model were used to assess factors associated with PCa, respectively. When we adjusted all the co-variables, the correlation was slightly stronger. It showed that high/old age (71 years or more compared with 60 to 70 years), smoking, having a higher BMI (24 kg/m^3 or more compared with less than 24 kg/m^3), higher CA19-9 were associated with a higher risk for a prostate cancer diagnosis (Table 3).

Discussion

Prostate cancer is a significant health concern in eastern China. The overall prevalence of PCa was 0.93%, and the age-standardized prevalence was 0.91%, which was lower than Canada (3.32%)[10], France (1.8%)[11] and Pakistan (5.20%)[12]. This disparity may be attributable to variations in research techniques, sample size, social, environmental, and genetic factors. Our study aimed to give helpful information about prostate cancer to the health authorities so that something can be done to prevent deadly diseases like PCa.

Variables	Prostate cancer		
	N	Prevalence	*p* value
Age (years)			< 0.0001
60–70	219	0.57	
71–80	333	1.29	
81 or above	83	1.65	
Education levels			0.352
Illiterate	18	0.26	
Primary school	431	1.08	
Middle school	197	1.05	
High school or above	36	0.78	
BMI (kg/m3)			0.1587
<18.5	15	0.63	
18.5–23.9	300	0.88	
24-27.9	271	0.99	
≥28	69	1.02	
Smoker			< 0.0001
Yes	238	1.04	
No	327	0.69	
Drinker			0.0022
Yes	306	1.03	
No	321	0.8	
High-salt diet			0.693
Yes	153	0.96	
No	502	0.92	
Regular exercise			0.1425
Yes	112	0.91	
No	606	1.05	
Hypertension			0.5084
Yes	283	0.96	
No	372	0.91	
Diabetes			0.1609
Yes	64	0.79	
No	591	0.95	
Dyslipemia			0.4242
Yes	341	0.96	
No	314	0.9	

Table 2. PCa prevalence among a elderly population stratified by demographic characteristics.

The results of this study suggested that the prevalence of PCa was closely related to age, and its prevalence increased with age, the older the age, the higher the incidence, which was also proved by other studies[11,14,14] The habit of tobacco consumption was showed as an associated risk factor of PCa in this study, another study also showed that a higher number of cigarettes per day to use was associated with a 30% higher risk of dying from PCa[16,16] But a study showed that current cigarette smoking was inversely associated with incident PCa, which gave a controversial conclusion[16,16,17] Heterogeneity present within the different studies precluded drawing conclusions to contemporary patients.

Alcohol has been showed to be associated with PCa in other studies[18], but no significant association was seen in the multivariate regression model of this study, although there was a higher PCa prevalence in the drinking group compared with the non-drinking group. One of the reasons might be that recent abstainers might have been included in the abstainer group. In our study, it showed that higher BMI (24 kg/m^3 or more compared with less than 24 kg/m^3) were associated with a higher risk for a prostate cancer diagnosis. Another study showed that the estimated OR for PCa for a 5 kg/m^2 increase in BMI was 0.98 (95% CI: 0.95–1.01)[19]. Higher PSA values (4 ng/ml or more compared with less than 4 ng/ml) were associated with a higher risk for a prostate cancer diagnosis, which had been confirmed in many other studies[9,13].

PCa screening has been widely carried out in Europe and the United States. For example, the death rate from PCa in the United States has declined in recent years, thanks in part to widespread and stringent prostate cancer screening policies[3]. Of course, as more and more advanced PCa is found and treated, the proportion of early PCa is increasing, and there may be a small amount of overdiagnosis and overtreatment. Therefore, there is currently

Variables	Crude analysis		Multivariate analysis	
	OR [CI 95%]	p^*	OR [CI 95%]	p^{**}
Age (years)				
60–70	1		1	
71–80	1.79 (1.54–2.09)	< 0.0001	1.64 (1.37–1.95)	< 0.0001
81 or above	1.90 (1.51–2.39)	< 0.0001	1.32 (1.01–1.73)	0.0459
Education levels				
Illiterate	1		1	
Primary school	1.17 (0.78–1.76)	0.4524	1.02 (0.67–1.55)	0.9383
Middle school	1.13 (0.62–2.06)	0.6876	0.91 (0.49–1.69)	0.7716
High school or above	0.84 (0.21–3.39)	0.807	0.63 (0.15–2.60)	0.5186
BMI (kg/m^3)				
<24	1		1	
24-27.9	1.12 (0.96–1.31)	0.168	1.19 (1.01–1.42)	0.042
≥28	1.14 (0.87–1.43)	0.4	1.35 (1.03–1.78)	0.0312
Smoker				
No	1		1	
Yes	1.54 (1.29–1.85)	< 0.0001	1.41 (1.17–1.70)	0.0004
Drinker				
No	1		1	
Yes	0.92 (0.87–1.97)	0.569	0.97 (0.91–1.02)	0.2314
High-salt diet				
No	1		1	
Yes	0.96 (0.80–1.16)	0.6891	0.95 (0.79–1.14)	0.5809
Meat-based diet				
No	1		1	
Yes	0.20 (0.03–1.44)	0.11	0.20 (0.03–1.41)	0.105
High oil diet				
No	1		1	
Yes	1.37 (0.57–3.33)	0.4834	1.41 (0.55–3.63)	0.476
High-sugar diet				
No	1			
Yes	1.15 (0.29–4.65)	0.8437	0.95 (0.22–4.15)	0.9595
Regular exercise				
No	1		1	
Yes	1.16 (0.96–1.40)	0.1367	1.10 (0.90–1.34)	0.3721
Hypertension				
No	1		1	
Yes	1.05 (0.90–1.23)	0.5078	0.96 (0.82–1.13)	0.6081
Diabetes				
No	1		1	
Yes	0.84 (0.64–1.08)	0.1712	0.82 (0.63–1.08)	0.1541
Dyslipemia				
No	1		1	
Yes	1.06 (0.91–1.24)	0.4244	1.08 (0.92–1.27)	0.3648
CEA				
<5	1		1	
≥ 5	1.29 (0.99–1.68)	0.056	1.16 (0.88–1.53)	0.295
AFP				
<9	1		1	
≥ 9	0.96 (0.51–1.79)	0.8907	0.90 (0.47–1.72)	0.757
CA19-9				
<39	1		1	
≥39	1.13 (0.66–1.91)	0.6643	1.79 (1.08–2.94)	0.0231

Table 3. Crude and multivariate odd ratio (OR) for independent in relation to PCa. Note: CEA, serum carcinoembryonic antigen; AFP, alpha fetal protein; CA19-9, carbohydrate antigen 19 – 9.

a great deal of controversy in Europe and the United States about population-based prostate cancer screening, and some policy guidelines would have the opposite situation. However, in China, because large-scale PCa screening has not begun, there should be a considerable number of highly aggressive or advanced PCa cases in the population. Therefore, at the present stage in China, a PSA based Pca screening strategy could be advisable.

Our study had several strengths and limitations. The main strength included that it was one of very few surveys about PCa prevalence and associated factors among a larger population in China. But some limitations needed to be mentioned in this study. First of all, this study was a cross-sectional survey, which was failed to establish cause-and-effect relationship between the observed associations. Second, some confounding variables including family history of diseases and family income were not included, and the definition of alcohol consumption was should more detailed. All of these called for further studies involving longer cohorts to verify our conclusion.

Conclusion

As we all know, symptomatic cancer patients diagnosed in the hospital setting are more often in the middle and late stage disease, with a lower probability of curative treatment, higher treatment costs, and there is often overtreatment. Early detection of cancers through screening and early intervention gives a higher probability of achieving cure, thus saving medical costs. The Pca prevalence is one of the increasingly important health problems among elderly men in eastern China, especially as the aging population is becoming more and more numerous. Faced with the demographic transition, we need innovative strategies to control and prevent PCa. Conducting early screening among male population in community health service centers, especially among a population with associated risk factors such as high age, smoking, having a higher BMI and higher CA19-9, and conducting community-based intervention programs might be helpful to address this increasingly significant health problem.

Data availability

The data set of this study is available from the corresponding author upon request.

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Author contributions

Jun Chen had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Jun Chen, Liang He. Acquisition of data: Liang He, Xing Wang, Junfeng Yan. Analysis and interpretation of data: Li Yang, Yixiu Ni, Feijun Yu, Aokang Zhang. Drafting of the manuscript: Liang He, Yixiu Ni. Critical revision of the manuscript for important intellectual content: Jun Chen, Liang He. Statistical analysis: Liang He, Xing Wang, Junfeng Yan. Obtaining funding: Jun Chen. Administrative, technical, or material support: Liang He. Supervision: Jun Chen.

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Declarations

Competing interests
The authors declare no competing interests.

Additional information
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