Journal of Occupational Medicine and Toxicology

RESEARCH

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Firefighting, other protective service occupations and prostate cancer risk: a pooled analysis of three case-control studies

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Abstract

Background Prostate cancer (PCa) is the most frequent incident cancer among males in industrialized countries, but little is known about its aetiology. A role for occupational exposures is suggested. Occupational exposure as a firefighter, a protective service occupation (PSO), is classified as carcinogenic to humans by the International Agency for Research on Cancer, with limited evidence in humans for PCa. We studied the association between PSO and PCa risk considering tumour aggressiveness and screening practices.

Methods The EPIdemiological study of Prostate Cancer (EPICAP), the Prostate cancer & Environment Study (PROtEuS) and the MultiCase-Control study in common tumours in Spain (MCC-Spain) are population-based case-control studies, conducted respectively in France, Canada, Spain, in 2005–2014 in men ≤ 85 years old, including overall 3,859 incident cases and 4,359 controls frequency-matched on age. Participants were interviewed face-to-face using general and occupational questionnaires covering all jobs held in career, coded according to the 1988 International Standard Classification of Occupations. Unconditional logistic regressions estimated associations between PSO and PCa, after adjusting for potential confounders. Two sets of analyses were conducted, without and with consideration of screening. The latter is believed to yield the main findings since less subject to detection bias.

Results When restricting controls to those recently screened, men employed as firefighters ≥ 10 years had increased risk (OR (Odds ratio) = 2.01 [95% confidence interval] [1.02; 3.97]) of non-aggressive PCa. Positive associations for non-aggressive PCa among men employed < 10 years as police officers (OR = 2.53 [1.07; 5.96]) and police inspectors and detectives (OR = 6.75 [1.47; 30.96]) were observed. Very few cases in PSO were characterized by aggressive tumours.

Conclusions Findings from this large population-based study corroborate the higher PCa risk previously reported among firefighters, but only for non-aggressive tumours. Screening practices had a substantial impact on risk estimates. Future studies should investigate specific exposures, and account for PCa aggressiveness and individual screening patterns.

Keywords Pooled study, Firefighters, Police officers, Armed forces, Prostate cancer aggressiveness

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Introduction

A continuous increase in the incidence of prostate cancer (PCa) has been observed since the 90s in high-income countries; making it the most common male cancer. This rise in PCa incidence reflects the increased use of transurethral resection of the prostate (TURP) surgeries and widespread prostate specific antigen (PSA) screening. In 2022, GLOBOCAN estimates 158,422 new cases of PCa in Western Europe, 96,952 in Southern Europe, and 255,782 in Northern America. Meanwhile, PCa represented the second cause of cancer death in males in Northern America and Western Europe and the third one in Southern Europe [1, 2].

Except for age, ethnicity, and family history of PCa in first-degree relatives, that are non-modifiable well-established risk factors, the aetiology for PCa remains largely unknown. Suspected risk factors include lifestyle and environmental exposures, including occupational circumstances and agents. An increased risk of PCa has been observed among farmers/agricultural workers, pesticide manufacturers and applicators, heavy/toxic metals and chemical workers, administrative and managerial workers, nightshift workers and men employed in protective service occupations (PSO) [3, 4].

Over the last decades, some studies have examined the risk of PCa in all PSO combined with conflicting results [5–7], while many studies have focused more specifically on some of these occupations such as firefighters, police workers, prison/security guards and armed forces.

Among them, *firefighters* have been the most studied and occupational exposure as a firefighter was recently classified by the International Agency for Research on Cancer (IARC) [8] as carcinogenic to humans based on sufficient evidence for mesothelioma and bladder cancer and limited evidence in humans for PCa. Indeed, even though positive associations were observed in several studies [9–15], chance, confounding and/or bias could not be ruled out with reasonable confidence.

Among other PSO, *police officers* may be at greater risk of developing PCa [5, 14–16], but findings are less consistent which may be due to the fact that certain studies presented limitations on the assessment of occupational history. No clear relationship with PCa was yet established for *prison and security guards* [5, 17] and more studies are still needed to evaluate their PCa risk. Finally, most studies on *armed forces* did not find excess risks, except in an occupational cohort among Vietnam war veterans [18] and two population-based case-control studies for aggressive cancer [6, 7], particularly with prolonged employment [7].

PSO usually involve exposure to different chemical, biological, physical, and psycho-social hazards potentially associated with PCa risk. These professionals can be chronically exposed to nightshift work, which was positively associated with PCa in previous studies [19, 20] and was classified in 2020 as probably carcinogenic to humans by IARC [21]. Men who worked in PSO are also subject to consistent chronic workplace stress, which was associated with an increased PCa risk before age 65 [22]. Moreover, these workers have strict physical aptitude requirements at recruitment, introducing a possible healthy worker effect [16, 23].

Despite this important literature, reliable conclusions among PSO are still difficult to draw considering methodological shortcomings. Most previous studies did not include an exhaustive occupational history and relied on current or longest-held job as proxies of lifetime exposure to PSO and did not consider duration of employment; others where often conducted in specific occupational cohorts. Few studies were based on sufficiently large samples to conduct in-depth analyses in subgroups, potential confounders were not thoroughly investigated; only three recent studies considered tumour aggressiveness in their analyses [5–7]. Most previous studies did not address the potential impact of screening (either by PSA or digital rectal examination) on the associations studied, which may have introduced screening bias into their findings. Since PCa detection rates can differ across occupational groups [24], it is essential to consider screening behaviour and evaluate tumour aggressiveness when studying risk incurred in specific occupations.

In this context, the main goal of the present study was to evaluate the risk of PCa in PSO overall and in subgroups, including firefighting, considering cancer aggressiveness and screening practices, in a pooled analysis of three case-control studies.

Methods

Study population

The current study is based on data from three population-based case-control studies: EPICAP (EPIdemiological study of Prostate CAncer) [7, 20, 25], PROtEuS (The Prostate cancer & Environment Study) [5, 26, 27] and MCC-Spain (MultiCase-Control study in common tumours in Spain) [19, 28] conducted respectively in France, Canada and Spain during 2005–2014. All were specifically conceived to address the role of environmental and occupational factors in the occurrence of PCa.

In EPICAP, eligible cases were males newly diagnosed with histologically confirmed PCa in 2012–2013, 75 years old or less, identified across all health centres in the department of Hérault, and living in this geographic area at the time of diagnosis. Eligible controls were men randomly selected among the general population, with no history of PCa, living in this department and frequency-matched on age (5-year age groups). Moreover, quotas based on broad occupational groups were defined to represent the occupational distribution in the general

population. The study finally included 819 incident cases (183 aggressive) and 879 controls, with response rates of 75% and 79%, respectively.

In PROtEuS, eligible cases were males newly diagnosed with PCa and histologically confirmed in one of the seven largest French-speaking hospitals in Montreal during 2005–2009, 75 years old or less, registered on the French-speaking electoral list and living in one of Montreal's 39 electoral districts. Eligible controls were males frequency-matched on age (5-year age groups), with no history of PCa, registered on the French-speaking electoral list, and living across the same districts as cases. A total of 1,937 incident cases (436 aggressive) and 1,994 controls were enrolled in the study, with response rates of 80% and 56%, respectively.

In MCC-Spain, eligible PCa cases were male aged 85 years old or less, newly diagnosed in 2008–2013, histologically confirmed in one of the 11 collaborating hospitals in seven Spanish regions and living in the same regions for six months or more. Eligible controls were frequency-matched on age (5-year age groups), sex and region with cases, with no history of PCa, and randomly selected from the administrative records of primary health care centres. In total, 1,115 incident cases of PCa (275 aggressive) and 1,493 controls, with response rates of 72% and 53% respectively, were included.

In total, the three studies involved 3,859 incident cases, including 893 aggressive cases, and 4,359 controls.

Data collection

In the three studies, participants were interrogated face-to-face by trained interviewers using standardized questionnaires. Sociodemographic characteristics, personal/family medical histories, lifestyle (e.g., recreational physical activity, smoking and alcohol consumption, dietary habits) and environmental (e.g., residential, and occupational histories) factors were collected.

Anthropometric measurements were also performed during interviews and blood, or saliva samples were collected. Clinical data were collected from cases' medical records. The Gleason score at diagnosis was extracted from pathology reports and was used to characterize PCa aggressiveness. Information on PCa detection tests by PSA and/or digital rectal examination was obtained during interview and/or from medical records.

Occupational assessment

Cases and controls completed an occupational questionnaire covering all jobs held, at least six months for EPICAP and one year for PROtEuS and MCC-Spain. Data on start and end dates, company names and addresses, and the description of main tasks performed were reported.

For each job held (excluding volunteering work), occupational codes were assigned by industrial hygienists blinded to the participant's case/control status. Occupations were coded using, for EPICAP, the 1968 International Standard Classification of Occupations (ISCO-68) further transcoded into the 1988 International Standard Classification of Occupations (ISCO-88); for PROtEuS, ISCO-88 codes were assigned directly; for MCC-Spain, the 1994 Spanish National Classification of Occupations (CNO-94) was transcoded into ISCO-88. ISCO-88 uses a decimal coding method with four levels, providing successively finer detail about each occupation: 1-digit major groups, 2-digit sub-major groups, 3-digit minor groups and 4-digit unit groups and this classification was selected for our pooled study.

In the present study, we used 1 minor group's code *(3-digit)* of PSOs (010-Armed forces) and 6 unit groups' codes *(4-digit)* of PSO (5161-Firefighters, 5162-Police officers, 5163-Prison guards, 5169-Protective service occupations not elsewhere classified (e.g., bodyguards, lifeguards, patrolmen/women), 3151-Building and fire inspectors, 3450-Police inspectors and detectives). Two additional broad variables of all PSO combined were further created for better comparison with literature data: one including all PSO and another one including PSO except armed forces.

Statistical analysis

For each occupational group, we used two exposure indicators: ever employment (no, yes) and lifetime cumulative duration of employment (in years). Then, we created different classes according to the quartile's distribution amongst exposed controls. Finally, for better comparison with previous studies, we opted for two cumulative duration classes (<10 years, ≥ 10 years). Only military personnel with more than two years of experience were included in the analyses, thereby excluding participants who completed military service (usually up to two years) without pursuing a career in the armed forces. We only considered PSOs' subgroups with at least ten participants (cases + controls ≥ 10) ever employed in the three studies combined.

Associations between the various PSO and PCa risk were studied using unconditional logistic regression models which yielded odds ratios (OR) and 95% confidence intervals (CI). Multinomial logistic regression models were carried out to examine associations based on PCa aggressiveness, using the Gleason score at diagnosis. If the score was <7 or equal to 7 (3 for the primary site and 4 for the secondary site), the tumour was considered as non-aggressive cancer and if it was equal to 7 ($4+3$) or ≥ 8, it was deemed to be aggressive, based on its prognosis [29].

Prostate cancer is known to be a highly screening-sensitive cancer and some occupations, such as some PSO tend to undergo regular occupational health

examinations which may include screening for prostate cancer. In order to reduce the potential for undiagnosed PCa among controls and to examine the possible role of screening on the associations studied we used two analytical approaches to assess associations between PSO and PCa risk. The first set of analyses included all participants (3,859 incident cases and 4,359 controls). The second set included all cases, but restricted controls to the 2,807 men who had undergone screening within two years of interview. The comparisons to recently screened controls are considered as our main results.

All analyses were systematically adjusted for the recognized PCa risk factors: age (in years), ethnic origin (Caucasian, other) and first-degree family history of PCa (no, yes). Models were also adjusted for potential confounders with a *p-value* < *0.1* in univariate analyses such as educational level (university, high school, primary school, less than primary (or none)), body-mass index (< 25 kg/m^2, 25–29 kg/m^2, ≥ 30 kg/m^2), intensity of physical activity (very active, moderately active, weakly active) based on quartiles of lifetime METs (metabolic equivalent task) in EPICAP and MCC-Spain and self-reported in PROtEuS and night-shift work (never, ever (defined as working three nights per month for one year or more)). Moreover, we adjusted the models on the three studies, using PROtEuS as reference study.

In the analyses of all PSO combined, the unexposed participants consisted of men never employed in any PSO subgroup. However, in the analyses of a specific PSO subgroup, we included all workers from the other subgroups within PSO in the unexposed category.

Pooled analyses involved data harmonization of occupational and clinical variables and potential confounders across the three studies. Gleason scores were missing for 39 cases, which were excluded from analyses.

Sensitivity analyses were also conducted where we applied a priori lag periods of 5 years and 10 years in our analyses to allow for a possible latency effect, which meant that men employed for the first time in any PSO's subgroup less than 5 years or 10 years prior to the reference date were considered as unexposed. In other analyses on specific PSO subgroups, we excluded workers from the other subgroups within PSO in the unexposed category. Finally, we evaluated associations by study to examine the differences of risks estimates in each study separately. Results from sensitivity analyses and those based on individual studies are presented using the entire sets of controls.

All statistical analyses were performed using SAS software (9.4 version).

Results

Selected characteristics of study participants from EPICAP, PROtEuS, MCC-Spain and the pooled study are presented in Table 1. The proportions of subjects with aggressive tumours were 22.6% (n = 182), 22.6% (n = 436) and 25.3% (n = 275) in EPICAP, PROtEuS, and MCC-Spain respectively. Participants were mostly Caucasian. The mean (± SD) age of participants was 65 years in EPICAP, 64 years in PROtEuS and 66 years in MCC-Spain. A first-degree family history of PCa was about twice as frequent among cases as controls in all contributing studies. Participants in MCC-Spain tended to have a lower educational level and were more often obese (≥ 30 kg/m^2) and less physically active than those in the other two studies. More subjects from EPICAP and MCC-Spain had ever held an occupation entailing nightshift than those from PROtEuS. 69% of controls in EPICAP were screened for PCa within the two years preceding the interview. Corresponding values were 75.8% for PROtEuS and 46.6% for MCC-Spain.

Main characteristics of PSO jobs among controls in EPICAP, PROtEuS, MCC-Spain and the pooled study are reported in Table 2. The most represented subgroups in all three studies, including the pooled study, were police officers and workers in PSO not elsewhere classified. In the pooled study, the highest mean cumulative employment durations were for firefighters [21.2 (11.2) years] and police officers [22.6 (11.1) years].

Table 3 presents the results from the pooled analyses of the association between PSO (never/ever and by duration of employment) and overall PCa risk based on all controls.

Using all available controls, we did not observe associations with overall PCa risk among men who had worked in PSO (Table 3). However, employment in firefighting was associated with a higher risk of overall PCa especially in men employed 10 years or more in this occupation (OR = 1.95 [1.04; 3.64]). Elevated risks were also observed among men ever employed as police officers (OR = 1.49 [1.03; 2.17], with a stronger association among those employed less than 10 years (OR = 2.11 [1.05; 4.24]). Moreover, police inspectors and detectives had elevated risks (OR = 1.90 [1.06; 3.40]) for ever exposure, particularly those who had worked less than 10 years (OR = 7.59 [1.70; 33.87]) even though with wide CI. Finally, men who had worked 10 years or more in armed forces tended to be at risk of PCa (OR = 1.90 [0.81; 4.45]).

Our main findings are presented in Table 4 where we studied the association between PSO (never/ever and by duration of employment) and overall PCa risk using only recently screened controls.

When restricting controls to those screened within 2 years of interview (Table 4), we did not observe associations with overall PCa risk among men who had worked

Table 1 Selected characteristics of the population of EPICAP, PROtEuS and MCC-Spain studies

Characteristics	Pooled study (*N* = 8218)			EPICAP (*N* = 1693)			PROtEuS (*N* = 3920)			MCC-Spain (*N* = 2605)		
	Cases	Controls	*p*-value[b]	Cases	Controls	*p*-value	Cases	Controls	*p*-value	Cases	Controls	*p*-value
	n[a] = 3859 (%)	*n* = 4359 (%)		*n* = 818 (%)	*n* = 875 (%)		*n* = 1929 (%)	*n* = 1991 (%)		*n* = 1112 (%)	*n* = 1493 (%)	
Gleason score			-			-			-			-
≤ 7[c]	2927 (76.6)	-		623 (77.4)	-		1490 (77.4)	-		814 (74.7)	-	
≥ 7[d]	893 (23.4)	-		182 (22.6)	-		436 (22.6)	-		275 (25.3)	-	
Age, in years			*< 0.001*			*0.150*			*< 0.001*			*< 0.001*
< 55	330 (8.5)	368 (8.4)		48 (5.9)	59 (6.7)		211 (10.9)	177 (8.9)		71 (6.4)	132 (8.9)	
55–59	535 (13.9)	512 (11.8)		99 (12.1)	99 (11.3)		311 (16.1)	268 (13.5)		125 (11.2)	145 (9.7)	
60–64	967 (25.1)	941 (21.6)		216 (26.4)	200 (22.9)		485 (25.2)	448 (22.5)		266 (23.9)	293 (19.6)	
65–69	1053 (27.3)	1150 (26.4)		274 (33.5)	283 (32.3)		496 (25.7)	522 (26.2)		283 (25.5)	345 (23.1)	
≥70	974 (25.2)	1388 (31.8)		181 (22.1)	234 (26.8)		426 (22.1)	576 (28.9)		367 (33.0)	578 (38.7)	
Ethnic origin			*0.409*			*0.402*			*0.006*			*0.031*
Caucasian	3579 (92.7)	4019 (92.3)		794 (97.1)	855 (97.7)		1689 (87.6)	1683 (84.5)		1096 (98.6)	1481 (99.4)	
Others	280 (7.3)	337 (7.7)		24 (2.9)	20 (2.3)		240 (12.4)	308 (15.5)		16 (1.4)	9 (0.6)	
First-degree family history of prostate cancer			*< 0.001*			*< 0.001*			*< 0.001*			*< 0.001*
No	2841 (77.7)	3746 (91.1)		548 (75.2)	722 (90.5)		1409 (75.8)	1737 (89.9)		884 (82.7)	1287 (93.2)	
Yes	815 (22.3)	365 (8.9)		181 (24.8)	76 (9.5)		449 (24.2)	195 (10.1)		185 (17.3)	94 (6.8)	
Educational level			*< 0.001*			*0.503*			*0.042*			*< 0.001*
University	1019 (26.4)	1184 (27.2)		260 (31.8)	260 (29.7)		589 (30.6)	610 (30.7)		170 (15.3)	314 (21.0)	
High school	667 (17.3)	888 (20.4)		112 (13.7)	109 (12.5)		313 (16.3)	374 (18.8)		242 (21.7)	405 (27.1)	
Primary school	1783 (46.3)	1851 (42.5)		376 (46.0)	434 (49.7)		968 (50.3)	932 (46.8)		439 (39.5)	485 (32.5)	
Less than primary (or none)	385 (10.0)	433 (9.9)		70 (8.5)	71 (8.1)		54 (2.8)	73 (3.7)		261 (23.5)	289 (19.4)	
Marital status			*0.020*			*0.193*			*0.316*			*0.812*
Married/domestic partnership	3065 (79.5)	3539 (81.3)		674 (82.4)	748 (85.5)		1426 (73.9)	1501 (75.4)		965 (86.9)	1290 (86.7)	
Divorced/separated/ single	642 (16.6)	629 (14.4)		115 (14.1)	98 (11.2)		430 (22.3)	406 (20.4)		97 (8.7)	125 (8.4)	
Widowed	151 (3.9)	185 (4.3)		29 (3.5)	29 (3.3)		73 (3.8)	83 (4.2)		49 (4.4)	73 (4.9)	
Smoking status			*0.133*			*0.362*			*0.798*			*0.210*
Non-smokers	1106 (28.7)	1187 (27.3)		240 (29.4)	246 (28.1)		537 (27.9)	544 (27.4)		329 (29.6)	397 (26.6)	
Former smokers	2080 (54.0)	2347 (53.9)		454 (55.6)	475 (54.3)		1046 (54.3)	1075 (54.0)		580 (52.2)	797 (53.5)	
Current smokers	669 (17.3)	821 (18.8)		123 (15.0)	154 (17.6)		343 (17.8)	370 (18.6)		203 (18.2)	297 (19.9)	
Regular alcohol drinking[e]			*0.283*			*0.576*			*0.584*			*0.805*
No	423 (11.7)	504 (12.5)		72 (8.8)	84 (9.6)		213 (11.1)	231 (11.6)		138 (15.6)	189 (16.0)	
Yes	3203 (88.3)	3539 (87.5)		744 (91.2)	790 (90.4)		1714 (88.9)	1759 (88.4)		745 (84.4)	990 (84.0)	

Table 1 (continued)

Characteristics	Pooled study (*N* = 8218)			EPICAP (*N* = 1693)			PROtEuS (*N* = 3920)			MCC-Spain (*N* = 2605)		
	Cases *n*[a]=3859 (%)	Controls *n* = 4359 (%)	*p*-value[b]	Cases *n* = 818 (%)	Controls *n* = 875 (%)	*p*-value	Cases *n* = 1929 (%)	Controls *n* = 1991 (%)	*p*-value	Cases *n* = 1112 (%)	Controls *n* = 1493 (%)	*p*-value
Body-mass index (2 years before reference date), in kg/m^2			*0.022*			*0.861*			*0.011*			*0.867*
<25	1241 (32.3)	1290 (30.5)		296 (36.7)	314 (36.5)		648 (33.8)	607 (30.7)		297 (26.7)	369 (26.5)	
25–29	1853 (48.3)	2020 (47.8)		377 (46.7)	394 (45.9)		919 (47.9)	940 (47.5)		557 (50.1)	686 (49.4)	
≥ 30	743 (19.4)	918 (21.7)		134 (16.6)	151 (17.6)		351 (18.3)	432 (21.8)		258 (23.2)	335 (24.1)	
Waist circumference, in centimetres			*0.308*			*0.082*			*0.091*			*0.782*
≤ 94	1097 (30.5)	1300 (31.5)		208 (25.8)	253 (29.6)		672 (37.4)	719 (40.2)		217 (21.7)	328 (22.2)	
> 94	2505 (69.5)	2823 (68.5)		599 (74.2)	602 (70.4)		1124 (62.6)	1071 (59.8)		782 (78.3)	1150 (77.8)	
Intensity of physical activity[f]			*< 0.001*			*0.151*			*0.106*			*< 0.001*
Very active	914 (23.7)	943 (21.8)		187 (23.0)	174 (20.0)		443 (23.0)	405 (20.4)		284 (25.6)	364 (24.7)	
Moderately active	1501 (39.0)	1655 (38.2)		282 (34.7)	347 (39.9)		914 (47.5)	938 (47.1)		305 (27.4)	370 (25.1)	
Weakly active	1436 (37.3)	1733 (40.0)		344 (42.3)	349 (40.1)		569 (29.5)	646 (32.5)		523 (47.0)	738 (50.2)	
Night shift work			*0.084*			*0.522*			*0.054*			*0.075*
Never	2527 (68.9)	2885 (70.7)		532 (65.0)	556 (63.5)		1282 (73.6)	1391 (76.4)		713 (64.2)	938 (67.6)	
Ever	1143 (31.1)	1198 (29.3)		286 (35.0)	319 (36.5)		460 (26.4)	430 (23.6)		397 (35.8)	449 (32.4)	
Last screening for prostate cancer before reference date, in years			-			-			*< 0.001*			*< 0.001*
> 2	65 (1.7)	739 (17.0)		0 (0.0)	61 (7.0)		4 (0.2)	425 (21.3)		61 (5.5)	253 (16.9)	
≤ 2	3721 (96.4)	2807 (64.4)		818 (100.0)	602 (68.8)		1909 (99.0)	1509 (75.8)		994 (89.4)	696 (46.6)	
Never screened (or do not know)	73 (1.9)	813 (18.6)		0 (0.0)	212 (24.2)		16 (0.8)	57 (2.9)		57 (5.1)	544 (36.5)	

Abbreviations: [a]n number of participants in each group; [b]*p*-value: Chi-2 test; [c]≤ 7 (3 + 4); [d]≥7 (4 + 3); [e]at least once a month for one year; [f]based on tertiles of lifetime METs (*metabolic equivalent task*) in EPICAP and MCC-Spain and predefined in PROtEuS

Table 2 Selected characteristics of protective service occupational jobs among controls

ISCO[a] 1988 Code / Protective service occupations		Number of participants *n*	Total number of PSO[b] jobs *n*	Cumulative duration in PSO jobs (in years)	
				Mean (± SD)	Minimum-Maximum
EPICAP (*N* = 818) / 6094 jobs	7.4 jobs per control				
• 5161 Firefighters		6	6	18.6 (14.6)	1–33
• 5162 Police officers		16	42	29.4 (4.9)	12–34
• 5163 Prison guards		1	1	2 (0)	2–2
• 5169 Protective service occupations not elsewhere classified		28	42	9.8 (10.4)	0.5–35
• 3151 Building and fire inspectors		3	5	15.3 (13.6)	1–28
• 3450 Police inspectors and detectives		3	5	18 (8.5)	10–27
• 010 Armed forces		9	12	7.4 (5.6)	3–17
PROtEuS (*N* = 1991) / 11 498 jobs	5.8 jobs per control				
• 5161 Firefighters		16	23	22.1 (10.0)	3–32
• 5162 Police officers		24	53	19.2 (12.3)	1–38
• 5163 Prison guards		6	8	17.8 (11.6)	2.5–31
• 5169 Protective service occupations not elsewhere classified		67	100	9.3 (9.3)	1–40.5
• 3151 Building and fire inspectors		2	3	8.3 (10.3)	1–15.5
• 3450 Police inspectors and detectives		16	25	19.8 (9.6)	1.5–32.5
• 010 Armed forces		35	38	5.5 (4.1)	3–23
MCC-Spain (*N* = 1493) / 5387 jobs	3.6 jobs per control				
• 5161 Firefighters		0	0	0 (0)	-
• 5162 Police officers		15	20	21 (11.2)	3–40
• 5163 Prison guards		0	0	0 (0)	-
• 5169 Protective service occupations not elsewhere classified		6	6	14.3 (14.2)	2–33
• 3151 Building and fire inspectors		1	1	15 (0)	15–15
• 3450 Police inspectors and detectives		1	1	45 (0)	45–45
• 010 Armed forces		6	9	12.1 (13.5)	3–30
Pooled study (*N* = 4359) / 22 979 jobs	5.3 jobs per control				
• 5161 Firefighters		22	29	21.2 (11.2)	1–33
• 5162 Police officers		55	115	22.6 (11.1)	1–40
• 5163 Prison guards		7	9	15.6 (12.2)	2–31
• 5169 Protective service occupations not elsewhere classified		101	148	9.7 (9.9)	0.5–40.5
• 3151 Building and fire inspectors		6	9	12.9 (10.4)	1–28
• 3450 Police inspectors and detectives		20	31	20.8 (10.6)	1.5–45
• 010 Armed forces		50	59	6.7 (6.3)	3–30

Abbreviations: [a]*ISCO* International standard classification of occupations, [b]*PSO* Protective service occupations

in PSO. However, employment as police officers was positively associated with overall PCa risk, especially in men who had worked less than 10 years (OR = 2.41 [1.06; 5.48]). Moreover, police inspectors and detectives had elevated risks, particularly when employed less than 10 years (OR = 5.94 [1.32; 26.69]) although with wide CI.

Table 5 presents the results from the pooled analyses of the association between PSO (never/ever and by duration of employment) and PCa risk by cancer aggressiveness, using all controls.

Based on all controls (Table 5), we observed positive associations with non-aggressive PCa among workers who were employed in PSO 10 years or more (OR = 1.38 [1.05; 1.83]). However, ORs for aggressive PCa among these groups were below unity. Ever employment as a firefighter was associated with an OR of 1.94 [1.08; 3.47] (29 cases) of non-aggressive cancer and an OR of 0.79 [0.27; 2.32] (4 cases) of aggressive cancer. Corresponding ORs for employment at least 10 years were 2.31 [1.21; 4.42] (25 cases) and 1.02 [0.34; 3.09] (4 cases), respectively. Positive associations were also found with non-aggressive PCa among workers employed as police officers and as police inspectors and detectives. For instance, employment less than 10 years as a police officer yielded an OR of 2.21 [1.06; 4.63] (17 cases), while it was of 8.62 [1.89; 39.26] (11 cases)

Table 3 Associations between protective service occupations and overall prostate cancer ($N=8218$)

ISCO[a] 1988 Code / Description		Never	Ever employed		Employed < 10 years		Employed ≥ 10 years	
		n[b]	*n*	OR [95% CI][c]	*n*	OR [95% CI]	*n*	OR [95% CI]
Protective service occupations	Controls	4125	234	1.00 reference	109	1.00 reference	125	1.00 reference
	All cases	3624	235	1.14 [0.93 ; 1.39]	96	1.02 [0.75 ; 1.39]	139	1.23 [0.94 ; 1.60]
Protective service occupations (except armed forces)	Controls	4170	189	1.00 reference	73	1.00 reference	116	1.00 reference
	All cases	3668	191	1.14 [0.91 ; 1.43]	64	1.04 [0.72 ; 1.49]	127	1.20 [0.91 ; 1.58]
• 5161 Firefighters	Controls	4337	22	1.00 reference	5	1.00 reference	17	1.00 reference
	All cases	3826	33	1.62 [0.92 ; 2.86]	4	0.66 [0.17 ; 2.60]	29	1.95 [1.04 ; 3.64]
• 5162 Police officers	Controls	4304	55	1.00 reference	13	1.00 reference	42	1.00 reference
	All cases	3788	71	1.49 [1.03 ; 2.17]	22	2.11 [1.05 ; 4.24]	49	1.30 [0.83 ; 2.01]
• 5163 Prison guards	Controls	4352	7	1.00 reference	3	1.00 reference	4	1.00 reference
	All cases	3848	11	1.25 [0.46 ; 3.36]	3	0.54 [0.09 ; 3.47]	8	1.78 [0.52 ; 6.05]
• 5169 Protective service occupations not elsewhere classified	Controls	4258	101	1.00 reference	64	1.00 reference	37	1.00 reference
	All cases	3784	75	0.84 [0.61 ; 1.17]	41	0.77 [0.50 ; 1.17]	34	0.97 [0.59 ; 1.59]
• 3151 Building and fire inspectors	Controls	4353	6	1.00 reference	2	1.00 reference	4	1.00 reference
	All cases	3855	4	0.57 [0.15 ; 2.21]	3	2.49 [0.24 ; 25.37]	1	0.16 [0.02 ; 1.48]
• 3450 Police inspectors and detectives	Controls	4339	20	1.00 reference	2	1.00 reference	18	1.00 reference
	All cases	3827	32	1.90 [1.06 ; 3.40]	13	7.59 [1.70 ; 33.87]	19	1.22 [0.62 ; 2.41]
• 010 Armed forces	Controls	4309	50	1.00 reference	41	1.00 reference	9	1.00 reference
	All cases	3811	48	1.11 [0.71 ; 1.73]	34	0.90 [0.53 ; 1.52]	14	1.90 [0.81 ; 4.45]

Abbreviations: [a]*ISCO* International standard classification of occupations, [b]*n* Number of participants in each group, [c]Odds ratio adjusted for age (continuous variable), ethnic origin, first-degree family history of this cancer, studies included in pooled analysis (study of reference: PROtEuS), educational level, body-mass index (2 years before reference date), intensity of physical activity and night shift work

Table 4 Associations between protective service occupations and overall prostate cancer in the pooled analysis, restricting controls to those screened within 2 years of interview (*N* = 6666)

ISCO[a] 1988 Code / Description		Never	Ever employed		Employed < 10 years		Employed ≥ 10 years	
		n[b]	*n*	OR [95% CI][c]	*n*	OR [95% CI]	*n*	OR [95% CI]
Protective service occupations	Controls	2640	167	1.00 reference	74	1.00 reference	93	1.00 reference
	All cases	3624	235	1.06 [0.85; 1.33]	96	0.99 [0.71; 1.38]	139	1.11 [0.84; 1.48]
Protective service occupations (except armed forces)	Controls	2672	135	1.00 reference	48	1.00 reference	87	1.00 reference
	All cases	3668	191	1.07 [0.83; 1.36]	64	1.05 [0.71; 1.57]	127	1.07 [0.79; 1.45]
• 5161 Firefighters	Controls	2790	17	1.00 reference	3	1.00 reference	14	1.00 reference
	All cases	3826	33	1.52 [0.83; 2.78]	4	0.81 [0.17; 3.85]	29	1.68 [0.87; 3.25]
• 5162 Police officers	Controls	2766	41	1.00 reference	8	1.00 reference	33	1.00 reference
	All cases	3788	71	1.37 [0.91; 2.07]	22	2.41 [1.06; 5.48]	49	1.12 [0.70; 1.79]
• 5163 Prison guards	Controls	2801	6	1.00 reference	2	1.00 reference	4	1.00 reference
	All cases	3848	11	1.07 [0.38; 3.03]	3	0.70 [0.09; 5.34]	8	1.24 [0.36; 4.26]
• 5169 Protective service occupations not elsewhere classified	Controls	2738	69	1.00 reference	43	1.00 reference	26	1.00 reference
	All cases	3784	75	0.82 [0.58; 1.17]	41	0.78 [0.49; 1.24]	34	0.88 [0.51; 1.51]
• 3151 Building and fire inspectors	Controls	2804	3	1.00 reference	1	1.00 reference	2	1.00 reference
	All cases	3855	4	0.53 [0.11; 2.61]	3	1.47 [0.14; 15.46]	1	0.14 [0.01; 1.81]
• 3450 Police inspectors and detectives	Controls	2791	16	1.00 reference	2	1.00 reference	14	1.00 reference
	All cases	3827	32	1.74 [0.94; 3.24]	13	5.94 [1.32; 26.69]	19	1.15 [0.56; 2.35]
• 010 Armed forces	Controls	2772	35	1.00 reference	29	1.00 reference	6	1.00 reference
	All cases	3811	48	1.08 [0.67; 1.75]	34	0.85 [0.48; 1.49]	14	2.08 [0.79; 5.53]

Abbreviations: [a]*ISCO* International standard classification of occupations, [b]n Number of participants in each group, [c]Odds ratio adjusted for age (continuous variable), ethnic origin, first-degree family history of this cancer, studies included in pooled analysis (study of reference: PROtEuS), educational level, body-mass index (2 years before reference date), intensity of physical activity and night shift work

among police inspectors and detectives, albeit with wide CI.

Our primary results by cancer aggressiveness are reported in Table 6 where we studied the association between PSO (never/ever and by duration of employment) and PCa risk based on recently screened controls.

When restricting controls to those recently screened (Table 6), there was a suggestion of an elevated risk of non-aggressive PCa among men who had worked in PSO 10 years or more (OR = 1.26 [0.93; 1.70] (115 cases). However, we did not observe associations among these groups for aggressive PCa. Elevated risks of non-aggressive PCa were observed among men ever employed in firefighting, and among those who had worked 10 years or more (OR = 2.01 [1.02; 3.97] (25 cases) while an OR of 0.86 [0.28; 2.66] (4 cases) was found for aggressive PCa. Ever employment as police officers was associated with a higher risk of non-aggressive PCa, especially in men employed less than 10 years (OR = 2.53 [1.07; 5.96] (17 cases) and an OR of 2.12 [0.68; 6.54] (5 cases) was observed for aggressive PCa. Furthermore, positive associations with non-aggressive PCa were found among men who had ever worked as police inspectors and detectives, especially less than 10 years (OR = 6.75 [1.47; 30.96] (11 cases) although with wide CI. Corresponding OR for aggressive PCa was 3.73 [0.52; 26.83] (2 cases).

In sensitivity analyses, when considering men who worked for the first time in each PSO's subgroup less than 5 years or 10 years prior to the reference date as unexposed to consider a potential PCa latency, risk estimates were mostly unchanged (Additional file 1: Tables S1-S4). Finally, results for analyses on specific PSO subgroups remained consistent when we excluded workers from the other subgroups within PSO in the unexposed category (Additional file 1: Tables S5-S6).

Results from individual studies were limited by the number of participants employed in the various PSO. In EPICAP, there was a suggestion of elevated risks among members of armed forces, especially for aggressive cancers (Additional file 2: Tables IS1-IS2). In PROtEuS, which was based on a larger sample, there were also suggestions of excess risks in police officers and police inspectors and detectives, and some more pronounced risks of non-aggressive cancers among firefighters and police officers (Additional file 2: Tables IS3-IS4). Finally, all PSO combined appeared to have some excess risks of non-aggressive cancers in MCC-Spain; however, we could not accurately estimate the risks by subgroup for many PSO categories due to small numbers of participants (including firefighters) (Additional file 2: Tables IS5-IS6).

Discussion

Our main findings, which account for screening, are consistent with an elevated risk of PCa among some PSO, particularly among men employed for less than 10

Table 5 Associations between protective service occupations and prostate cancer aggressiveness (*N* = 8179)

ISCO[a] 1988 Code / Description		Never	Ever employed		Employed < 10 years		Employed ≥ 10 years	
		n[b]	*n*	OR [95% CI][c]	*n*	OR [95% CI]	*n*	OR [95% CI]
Protective service occupations	Controls	4125	234	1.00 reference	109	1.00 reference	125	1.00 reference
	Non-aggressive	2740	187	1.23 [0.99 ; 1.52]	72	1.03 [0.74 ; 1.43]	115	1.38 [1.05 ; 1.83]
	Aggressive	847	46	0.87 [0.61 ; 1.24]	22	0.94 [0.57 ; 1.56]	24	0.83 [0.52 ; 1.32]
Protective service occupations (except armed forces)	Controls	4170	189	1.00 reference	73	1.00 reference	116	1.00 reference
	Non-aggressive	2774	153	1.24 [0.98; 1.58]	47	1.04 [0.70; 1.55]	106	1.36 [1.02; 1.82]
	Aggressive	857	36	0.83 [0.56; 1.22]	15	0.95 [0.52; 1.74]	21	0.77 [0.47; 1.26]
• 5161 Firefighters	Controls	4337	22	1.00 reference	5	1.00 reference	17	1.00 reference
	Non-aggressive	2898	29	1.94 [1.08 ; 3.47]	4	0.83 [0.21 ; 3.32]	25	2.31 [1.21 ; 4.42]
	Aggressive	889	4	0.79 [0.27 ; 2.32]	0	-	4	1.02 [0.34 ; 3.09]
• 5162 Police officers	Controls	4304	55	1.00 reference	13	1.00 reference	42	1.00 reference
	Non-aggressive	2869	58	1.65 [1.11 ; 2.45]	17	2.21 [1.06 ; 4.63]	41	1.47 [0.92 ; 2.33]
	Aggressive	880	13	1.10 [0.59 ; 2.05]	5	1.86 [0.65 ; 5.27]	8	0.86 [0.40 ; 1.87]
• 5163 Prison guards	Controls	4352	7	1.00 reference	3	1.00 reference	4	1.00 reference
	Non-aggressive	2917	10	1.60 [0.59 ; 4.33]	2	0.70 [0.11 ; 4.53]	8	2.27 [0.66 ; 7.79]
	Aggressive	892	1	-	1	-	0	-
• 5169 Protective service occupations not elsewhere classified	Controls	4258	101	1.00 reference	64	1.00 reference	37	1.00 reference
	Non-aggressive	2870	57	0.87 [0.61 ; 1.23]	30	0.75 [0.47 ; 1.19]	27	1.06 [0.63 ; 1.80]
	Aggressive	876	17	0.75 [0.43 ; 1.31]	10	0.77 [0.37 ; 1.57]	7	0.72 [0.30 ; 1.74]
• 3151 Building and fire inspectors	Controls	4353	6	1.00 reference	2	1.00 reference	4	1.00 reference
	Non-aggressive	2925	2	0.35 [0.07 ; 1.90]	2	2.37 [0.20 ; 27.91]	0	-
	Aggressive	892	1	0.90 [0.10 ; 7.87]	0	-	1	1.00 [0.11 ; 9.29]
• 3450 Police inspectors and detectives	Controls	4339	20	1.00 reference	2	1.00 reference	18	1.00 reference
	Non-aggressive	2902	25	1.97 [1.06 ; 3.64]	11	8.62 [1.89 ; 39.26]	14	1.19 [0.57 ; 2.47]
	Aggressive	886	7	1.73 [0.71 ; 4.18]	2	4.78 [0.67 ; 34.27]	5	1.36 [0.49 ; 3.74]
• 010 Armed forces	Controls	4309	50	1.00 reference	41	1.00 reference	9	1.00 reference
	Non-aggressive	2890	37	1.13 [0.70 ; 1.82]	26	0.89 [0.50 ; 1.59]	11	2.01 [0.82 ; 4.92]
	Aggressive	882	11	1.10 [0.54 ; 2.21]	8	0.95 [0.42 ; 2.18]	3	1.63 [0.44 ; 6.10]

Abbreviations: [a]*ISCO* International standard classification of occupations, [b]*n* Number of participants in each group, [c]Odds ratio adjusted for age (continuous variable), ethnic origin, first-degree family history of this cancer, studies included in pooled analysis (study of reference: PROtEuS), educational level, body-mass index (2 years before reference date), intensity of physical activity and night shift work

years as police officers and police inspectors and detectives. We also found elevated risks of non-aggressive PCa among firefighters employed ≥ 10 years, and among police officers, police inspectors and detectives who worked < 10 years. There was no evidence of excess risks of aggressive cancers in PSO, including firefighters, once screening patterns were considered although the number of exposed men with high-grade cancers was small.

One striking observation is that associations were generally attenuated when restricting controls to those screened within 2 years of interview and that most confidence intervals now included the null value. The excess risks observed were for non-aggressive cancers and/or for periods of employment of less than 10 years. Altogether, these findings appear to reflect a screening bias, whereas elevated risks would be found for less aggressive disease and among men with a shorter period of employment that often occurred more recently, as they may be subjected to a closer medical monitoring. Due to the nature of their usual tasks, regular occupational health checkups are mandatory throughout their careers, possibly influencing their screening behaviour and leading to PCa diagnoses at a younger age than the general population [16, 23]. In our control series, men employed in PSO had a higher prevalence of recent screening (82%) than other controls (79%). The corresponding prevalence was even higher among firefighters and police officers (90%).

Positive associations with overall PCa have been previously observed among men ever employed in PSO [30, 31] and in men with prolonged exposure to PSO [5]. In our pooled analysis, there was a suggestion of an elevated OR among those employed 10 years or more, specifically for non-aggressive PCa.

We identified six meta-analyses that showed a slight excess risk among firefighters [9–13, 15], particularly when employed > 20 years [10]. The elevated PCa risk among long-term firefighters observed in our study (without taking screening into account) is in agreement with findings from previous population-based case-control studies [32, 33] and cohorts [16, 34], particularly among workers employed 20 years or more [34]. When we considered screening practices, this association

Table 6 Associations between protective service occupations and prostate cancer aggressiveness in the pooled analysis, restricting controls to those screened within 2 years of interview (*N* = 6627)

ISCO[a] 1988 Code / Description		Never	Ever employed		Employed < 10 years		Employed ≥ 10 years	
		n[b]	*n*	OR [95% CI][c]	*n*	OR [95% CI]	*n*	OR [95% CI]
Protective service occupations	Controls	2640	167	1.00 reference	74	1.00 reference	93	1.00 reference
	Non-aggressive	2740	187	1.14 [0.90; 1.45]	72	1.00 [0.70; 1.43]	115	1.26 [0.93; 1.70]
	Aggressive	847	46	0.81 [0.57; 1.17]	22	0.92 [0.54; 1.54]	24	0.75 [0.46; 1.21]
Protective service occupations (except armed forces)	Controls	2672	135	1.00 reference	48	1.00 reference	87	1.00 reference
	Non-aggressive	2774	153	1.16 [0.90; 1.51]	47	1.06 [0.69; 1.62]	106	1.22 [0.89; 1.67]
	Aggressive	857	36	0.77 [0.52; 1.16]	15	0.96 [0.51; 1.80]	21	0.69 [0.41; 1.14]
• 5161 Firefighters	Controls	2790	17	1.00 reference	3	1.00 reference	14	1.00 reference
	Non-aggressive	2898	29	1.83 [0.98; 3.43]	4	1.04 [0.22; 5.02]	25	2.01 [1.02; 3.97]
	Aggressive	889	4	0.71 [0.24; 2.15]	0	-	4	0.86 [0.28; 2.66]
• 5162 Police officers	Controls	2766	41	1.00 reference	8	1.00 reference	33	1.00 reference
	Non-aggressive	2869	58	1.52 [0.99; 2.33]	17	2.53 [1.07; 5.96]	41	1.26 [0.77; 2.08]
	Aggressive	880	13	1.01 [0.53; 1.92]	5	2.12 [0.68; 6.54]	8	0.74 [0.34; 1.65]
• 5163 Prison guards	Controls	2801	6	1.00 reference	2	1.00 reference	4	1.00 reference
	Non-aggressive	2917	10	1.36 [0.48; 3.92]	2	0.90 [0.12; 7.01]	8	1.58 [0.46; 5.50]
	Aggressive	892	1	-	1	-	0	-
• 5169 Protective service occupations not elsewhere classified	Controls	2738	69	1.00 reference	43	1.00 reference	26	1.00 reference
	Non-aggressive	2870	57	0.84 [0.58; 1.23]	30	0.76 [0.46; 1.25]	27	0.96 [0.54; 1.70]
	Aggressive	876	17	0.73 [0.41; 1.29]	10	0.77 [0.37; 1.61]	7	0.68 [0.27; 1.67]
• 3151 Building and fire inspectors	Controls	2804	3	1.00 reference	1	1.00 reference	2	1.00 reference
	Non-aggressive	2925	2	0.32 [0.05; 2.19]	2	1.44 [0.12; 17.52]	0	-
	Aggressive	892	1	0.88 [0.09; 8.85]	0	-	1	1.01 [0.09; 11.70]
• 3450 Police inspectors and detectives	Controls	2791	16	1.00 reference	2	1.00 reference	14	1.00 reference
	Non-aggressive	2902	25	1.81 [0.95; 3.48]	11	6.75 [1.47; 30.96]	14	1.12 [0.52; 2.42]
	Aggressive	886	7	1.57 [0.64; 3.89]	2	3.73 [0.52; 26.83]	5	1.26 [0.45; 3.56]
• 010 Armed forces	Controls	2772	35	1.00 reference	29	1.00 reference	6	1.00 reference
	Non-aggressive	2890	37	1.10 [0.65; 1.84]	26	0.84 [0.46; 1.54]	11	2.21 [0.80; 6.13]
	Aggressive	882	11	1.06 [0.51; 2.19]	8	0.89 [0.38; 2.10]	3	1.74 [0.43; 7.06]

Abbreviations: [a]*ISCO* International standard classification of occupations, [b]*n* Number of participants in each group, [c]Odds ratio adjusted for age (continuous variable), ethnic origin, first-degree family history of this cancer, studies included in pooled analysis (study of reference: PROtEuS), educational level, body-mass index (2 years before reference date), intensity of physical activity and night shift work

disappeared. Moreover, in our study, the excess PCa risk in firefighters was confined to non-aggressive cancers. Cancer aggressiveness was not considered in those previous studies.

A few recent studies also have observed elevated risks associated with ever employment as police officers or police inspectors and detectives [16, 17], including from the Nordic Occupational Cancer studies (NOCCA) cohort [35]. However, duration of employment as well as cancer aggressiveness or cancer detection were not considered in these studies. A previous publication based on the PROtEuS study reported an increased risk of non-aggressive PCa among police officers and detectives [5]. Moreover, one meta-analysis showed a slight excess risk of PCa among policemen, however duration of employment and cancer aggressiveness were not considered [15].

Elevated risks of overall PCa were found among men in the armed forces in two population-based studies from the NOCCA cohort [30, 31]. The elevated risks of PCa observed in our study were based on too few participants to draw conclusions.

Men who work in PSO are intermittently or acutely exposed to various chemical agents in their working environment. Many of them are known or suspected to be carcinogenic, or are recognized endocrine disruptors, which can be relevant to the carcinogenesis of a hormone-dependant organ such as the prostate. More studies with strong methodological protocols may help resolved this.

Firefighters can be exposed to combustion products from fires (e.g., polycyclic aromatic hydrocarbons (PAH) and particulates), building materials (e.g., asbestos), chemicals in firefighting foams (e.g., perfluorinated and polyfluorinated substances (PFAS)), flame retardants or diesel engine exhaust [8]. In PROtEuS, a weak positive association with non-aggressive PCa was found with occupational exposure to PAH from wood, especially among firefighters [36].

In our pooled analysis, the positive associations observed among police officers and police inspectors and detectives pertained to men who had worked less than 10 years, which could reflect recent concerns and closer medical attention among workers in these occupations. While we often assume long latency periods for solid tumours, shorter latencies have been reported in some contexts including menopausal hormone treatment and breast cancer risk. Given the limitations of using duration of employment as a recognized poor proxy for occupational exposure, the observed inverse-exposure relationship could also reflect exposure misclassification or other biases. Alternatively, these results could be chance findings or be associated with job-related specific exposures.

Our pooled analysis, combining studies with similar protocols and conducted over the same time frames, benefited from a large sample size (3,859 cases, 4,359 controls), thus providing greater precision than previous studies. Despite this, numbers in some analytical subgroups were quite small. Response rates were relatively high although some selection bias is possible, especially among controls, selected from the general population. In EPICAP, quotas based on broad occupational groups were applied to the control series to reflect those in the source population. In PROtEuS, a comparison of the socio-demographic characteristics of participants and non-participants revealed only marginal differences, reassuring against selection bias. Nevertheless, selection bias cannot be eliminated in MCC-Spain, where the participation rate was lower.

In addition, all three studies collected a complete work history covering all jobs held with detailed information on specific tasks, which informed the assignment of jobs titles by industrial hygienists blinded to the case/control status of participants. In this study, we were able to cover a wide range of PSO, to derive different indicators of exposure, to use a strategy to assess the potential impact of screening on the associations studied, to conduct different sensitivity analyses and to consider several potential confounders.

Ethnic origin is an established risk factor for PCa and men of sub-Saharan African descent are the most at risk [37]. Due to unavailability of detailed data on ethnicity, we could only distinguish the Caucasian participants from the other ethnic origins when adjusting our models.

Recall bias resulting from the use of self-reported work history is possible, although a high concordance between data collected from self-reported questionnaires and historical employment records has been documented [38].

It has previously been demonstrated that occupational groups may have different PCa screening practices [24]. As PSO tend to be more frequently than non-PSO in contact with the occupational health system, this could result in distorted PCa risk estimates due to screening bias. Associations were indeed attenuated when restricting controls to those screened recently and elevated risks were largely confined to low-grade cancers.

Conclusions

Our ability to study tumour aggressiveness and account for screening practices at the individual level distinguishes this work from most others. We documented associations between some PSO over shorter employment durations and risk of non-aggressive PCa.

Our findings also contribute evidence on several PSO subgroups that were rarely studied. Future epidemiological studies should be based on exposure to various PSO, consider tumour aggressiveness and PCa screening behaviour, and investigate chemical, physical and psychosocial circumstances that are specific to those occupations.

Abbreviations

PCa	Prostate cancer
PSO	protective service occupations
IARC	International agency for research on cancer
EPICAP	EPIdemiological study of prostate cancer
PROtEuS	The prostate cancer & environment study
MCC-Spain	Multicase-control study in common tumours in Spain
IRB-Inserm	Institutional review board of the French national institute of health and medical research
CNIL	French data protection authority
PSA	prostate specific antigen
ISCO	International standard classification of occupations
CNO	Spanish national classification of occupations
OR	odds ratios
CI	95% confidence intervals
MET	metabolic equivalent task
NOCCA	Nordic occupational cancer studies
PAH	polycyclic aromatic hydrocarbons
PFAS	perfluorinated and polyfluorinated substances
TURP	transurethral resection of the prostate

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12995-025-00464-7.

Additional file 1. Results from sensitivity analyses. Table S1. Associations between protective service occupations and overall prostate cancer in the pooled analysis, applying a lag period of 5 years (***N***=8218). Table S2. Associations between protective service occupations and prostate cancer aggressiveness in the pooled analysis, applying a lag period of 5 years (***N***=8179). Table S3. Associations between protective service occupations and overall prostate cancer in the pooled analysis, applying a lag period of 10 years (***N***=8218). Table S4. Associations between protective service occupations and prostate cancer aggressiveness in the pooled analysis, applying a lag period of 10 years (***N***=8179). Table S5. Associations between protective service occupations and overall prostate cancer in the pooled analysis, using the same reference group for all protective service occupational subgroups. Table S6. Associations between protective service occupations and prostate cancer aggressiveness in the three pooled analysis, using the same reference group for all protective service occupational subgroups.

Additional file 2. Results from individual studies. Table IS1. Associations between protective service occupations and overall prostate cancer in EPICAP (***N***=1693). Table IS2. Associations between protective service occupations and prostate cancer aggressiveness in EPICAP (***N***=1680). Table IS3. Associations between protective service occupations and overall prostate cancer in PROtEuS (*N*=3920). Table IS4. Associations between

protective service occupations and prostate cancer aggressiveness in PROtEuS ($N=3917$). Table IS5. Associations between protective service occupations and overall prostate cancer in MCC-Spain ($N=2605$). Table IS6. Associations between protective service occupations and prostate cancer aggressiveness in MCC-Spain ($N=2582$).

Acknowledgements
For the EPICAP study, we would like to thank the clinical research nurses who were in charge of participants' interview, anthropometric measurements, and biological sample collection (Anne-Laure Astolfi, Coline Bernard, Oriane Boyer, Marie-Hélène De Campo, Sandrine Margaroli, Louise N'Diaye, Sabine Perrier-Bonnet). We also would like to thank Christian Prad and Nadine Soller for help with patient medical data collection within the Hérault Cancer Registry (Registre des tumeurs de l'Hérault, Montpellier, France).
We are grateful to the EPICAP study Group:
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Pathologists: Drs Didier Brel, Lysiane Schweizer, Philippe Nayraud, C. Lecam-Savin (Béziers), Roland Daniel, Jean Baptiste Perdigou, Chantal Compan, Mireille Granier, Jean Louis Bouzigues, Elisabeth Broquerie, Joëlle Simony, Frédéric Bibeau, Pierre Baldet, Isabelle Serre (Montpellier), Marie Laure Gaume (Sète).
For the PROtEuS study, the authors would like to acknowledge the entire fieldwork team at the Institut national de la recherche scientifique who were involved in the data collection of PROtEuS as well as urologists for granting access to patients.
For the MCC-Spain study, we would like to thank Ana Espinosa for preparing the MCC-Spain dataset and the members of the steering committee of the study: Núria Aragonés (ISCIII, Madrid), Beatriz Pérez (ISCIII, Madrid), Adonina Tardón (UNIOVI), Trinidad Dierssen-Sotos (University of Cantabria), Pilar Amiano (Ministry of Health of the Basque Government), Rafael Marcos-Gragera (Epidemiology Unit and Girona Cancer Registry), José Juan Jiménez-Moleón (University of Granada), Victor Moreno (Catalan Institute of Oncology-ICO), Yolanda Benavente (Catalan Institute of Oncology-ICO), Delphine Casabonne (Catalan Institute of Oncology-ICO), Vicente Martín (University of León), María Dolores Chirlaque (Regional Health Council, Murcia), Marcela Guevara (Instituto de Salud Pública y Laboral de Navarra), Ana Molina-Barceló (Foundation for the Promotion of Health and Biomedical Research (FISABIO-Public Health) and all other investigators of the MCC-Spain study.

Authors' contributions
FM, MEP, MP and MK worked on the study concept, study design and data acquisition. HR and GCV did the data management. WB did the statistical analyses. WB, FM, MEP, MK and KS worked on the interpretation of data and the drafting of the manuscript. All authors read and approved the final manuscript.

Funding
EPICAP was funded by Ligue nationale contre le cancer, Ligue contre le cancer du Val-de-Marne, Fondation de France, Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES).
PROtEuS was supported financially through grants from the Canadian Cancer Society (grants no. 13149, 19500, 19864 and 19865), the Cancer Research Society, the Fonds de Recherche du Québec—Santé (FRQS), FRQS-Réseau de recherche en santé environnementale, the Ministère du Développement économique, de l'Innovation et de l'Exportation du Québec, and the Canadian Institutes of Health Research (grant no. 159704).
The MCC-Spain study was partially funded by the "Accion Transversal del Cancer", approved on the Spanish Ministry Council on the 11th October 2007, by the Instituto de Salud Carlos III-FEDER (PI08/1770, PS09/00773, PS09/01286, PS09/01903, PS09/02078, PS09/01662, PI11/01889-FEDER, PI12/00265, PI12/01270, PI12/00715, PI15/00914), by the Fundación Marqués de Valdecilla (API 10/09), by the Junta de Castilla y León (LE22A10-2), by the Consejería de Salud of the Junta de Andalucía (PI-0571-2009, PI-0306-2011, salud201200057018tra), by the Conselleria de Sanitat of the Generalitat Valenciana (AP_061/10), by the Regional Government of the Basque Country, by the Consejería de Sanidad de la Región de Murcia, by the Spanish Association Against Cancer (AECC) Scientific Foundation, by the Catalan Government- Agency for Management of University and Research Grants (AGAUR) grants 2017SGR723 and 2014SGR850, by the Fundación Caja de Ahorros de Asturias and by the University of Oviedo. ISGlobal acknowledges support from the grant CEX2018-000806-S funded by MCIN/AEI/ https://doi.org/10.13039/501100011033, and support from the Generalitat de Catalunya through the CERCA Program.
The funders of the three studies were not directly involved in the study design, the collection, analysis and interpretation of the data, the writing and the decision to submit the paper for publication.

Data availability
The datasets used and/or analysed during the current study are available from the authors on reasonable requests.

Declarations

Ethics approval and consent to participate
All participants signed a written informed consent. All studies were validated by the competent ethics committees and data protection authorities in each country. EPICAP was approved by the Institutional Review Board of the French National Institute of Health and Medical Research (IRB-Inserm n° 01–040) and by the French data Protection Authority (CNIL n° 910485). PROtEuS was validated by the Ethics Committees of the following institutions: Institut national de la recherche scientifique, Centre de Recherche du Centre Hospitalier de l'Université de Montréal, Hôpital Maisonneuve-Rosemont, Hôpital Jean-Talon, Hôpital Fleury, and Hôpital Charles-LeMoyne. MCC-Spain was approved by the Ethics committees of the 11 participating institutions and the database was registered in the Spanish Agency for Data Protection (n° 2102672171).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 21 January 2025 / Accepted: 16 May 2025
Published online: 10 June 2025

References

1. Bray F, Laversanne M, Sung H, Ferlay J, Siegel RL, Soerjomataram I, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2024;74(3):229–63.
2. Ferlay JEM, Lam F, Laversanne M, Colombet M, Mery L, Piñeros M, Znaor A, Soerjomataram I, Bray F. Global cancer observatory: Cancer Today Lyon, France: International Agency for Research on Cancer; 2024. Available from: https://gco.iarc.who.int/today.
3. Doolan G, Benke G, Giles G. An update on occupation and prostate cancer. Asian Pac J Cancer Prev. 2014;15(2):501–16.
4. Ledda C, Bracci M, Spadafora A, Motta G, Smecca G, Catelan D, Rapisarda V. Unmasking the Hidden Danger: A Decade-Long Systematic Review of Case–Control Studies on Single Occupational Risks and Prostate Cancer. Life. 2023;13(9):1820. https://doi.org/10.3390/life13091820.
5. Sauvé JF, Lavoué J, Parent M. Occupation, industry, and the risk of prostate cancer: a case-control study in Montréal, Canada. Environ Health. 2016;15(1):100.
6. Adler C, Friesen MC, Yeboah ED, Tettey Y, Biritwum RB, Adjei AA, et al. Usual adult occupation and risk of prostate cancer in West African men: the Ghana prostate study. Occup Environ Med. 2019;76(2):71–7.
7. Bijoux W, Cordina-Duverger E, Balbolia S, Lamy PJ, Rebillard X, Tretarre B, et al. Occupation and prostate Cancer risk: results from the epidemiological study of prostate cancer (EPICAP). J Occup Med Toxicol. 2022;17(1):5.
8. IARC Monographs Working Group Volume 132. Occupational exposure as a firefighter: IARC monographs on the identification of carcinogenic hazards to humans. Lyon, France: International Agency for Research on Cancer; 2023.
9. Casjens S, Brüning T, Taeger D. Cancer risks of firefighters: a systematic review and meta-analysis of secular trends and region-specific differences. Int Arch Occup Environ Health. 2020;93(7):839–52.
10. DeBono NL, Daniels RD, Beane Freeman LE, Graber JM, Hansen J, Teras LR, et al. Firefighting and cancer: A Meta-analysis of cohort studies in the context of Cancer hazard identification. Saf Health Work. 2023;14(2):141–52.
11. Jalilian H, Ziaei M, Weiderpass E, Rueegg CS, Khosravi Y, Kjaerheim K. Cancer incidence and mortality among firefighters. Int J Cancer. 2019;145(10):2639–46.
12. Lee DJ, Ahn S, McClure LA, Caban-Martinez AJ, Kobetz EN, Ukani H, et al. Cancer risk and mortality among firefighters: a meta-analytic review. Front Oncol. 2023;13:1130754.
13. Soteriades ES, Kim J, Christophi CA, Kales SN. Cancer incidence and mortality in firefighters: A State-of-the-Art review and Meta-Ānalysis. Asian Pac J Cancer Prev. 2019;20(11):3221–31.
14. Sritharan J, Kirkham TL, MacLeod J, Marjerrison N, Lau A, Dakouo M, et al. Cancer risk among firefighters and Police in the Ontario workforce. Occup Environ Med. 2022;79(8):533–9.
15. Sritharan J, Pahwa M, Demers PA, Harris SA, Cole DC, Parent ME. Prostate cancer in firefighting and Police work: a systematic review and meta-analysis of epidemiologic studies. Environ Health. 2017;16(1):124.
16. Harris MA, Kirkham TL, MacLeod JS, Tjepkema M, Peters PA, Demers PA. Surveillance of cancer risks for firefighters, police, and armed forces among men in a Canadian census cohort. Am J Ind Med. 2018;61(10):815–23.
17. Sritharan J, MacLeod JS, McLeod CB, Peter A, Demers PA. Prostate cancer risk by occupation in the occupational disease surveillance system (ODSS) in Ontario, Canada. Health Promot Chronic Dis Prev Can. 2019;39(5):178–86.
18. Yi SW. Cancer incidence in Korean Vietnam veterans during 1992–2003: the Korean veterans health study. J Prev Med Public Health. 2013;46(6):309–18.
19. Papantoniou K, Castaño-Vinyals G, Espinosa A, Aragonés N, Pérez-Gómez B, Burgos J, et al. Night shift work, chronotype and prostate cancer risk in the MCC-Spain case-control study. Int J Cancer. 2015;137(5):1147–57.
20. Wendeu-Foyet MG, Bayon V, Cénée S, Trétarre B, Rébillard X, Cancel-Tassin G, et al. Night work and prostate cancer risk: results from the EPICAP study. Occup Environ Med. 2018;75(8):573–81.
21. IARC Monographs Working Group Volume 124. Night shift work: IARC monographs on the identification of carcinogenic hazards to humans. Lyon, France: International Agency for Research on Cancer; 2020.
22. Blanc-Lapierre A, Rousseau MC, Parent ME. Perceived workplace stress is associated with an increased risk of prostate Cancer before age 65. Front Oncol. 2017;7:269.
23. Jakobsen J, Veierød MB, Grimsrud TK, Fosså SD, Hammarström B, Kjærheim K. Early detection of prostate cancer in firefighters: a register-based study of prognostic factors and survival. Occup Environ Med. 2022;79(3):200–6.
24. Peters CE, Villeneuve PJ, Parent M. Occupation as a predictor of prostate cancer screening behaviour in Canada. J Med Screen. 2020;27(4):215–22.
25. Menegaux F, Anger A, Randrianasolo H, Mulot C, Laurent-Puig P, Iborra F, et al. Epidemiological study of prostate cancer (EPICAP): a population-based case-control study in France. BMC Cancer. 2014;14:106.
26. Blanc-Lapierre A, Sauvé JF, Parent ME. Occupational exposure to benzene, toluene, xylene and styrene and risk of prostate cancer in a population-based study. Occup Environ Med. 2018;75(8):562–72.
27. Barul C, Richard H, Parent ME. Night-Shift work and risk of prostate cancer: results from a Canadian Case-Control study, the prostate Cancer and environment study. Am J Epidemiol. 2019;188(10):1801–11.
28. Castaño-Vinyals G, Aragonés N, Pérez-Gómez B, Martín V, Llorca J, Moreno V, et al. Population-based multicase-control study in common tumors in Spain (MCC-Spain): rationale and study design. Gac Sanit. 2015;29(4):308–15.
29. Chan TY, Partin AW, Walsh PC, Epstein JI. Prognostic significance of Gleason score 3 + 4 versus Gleason score 4 + 3 tumor at radical prostatectomy. Urology. 2000;56(5):823–7.
30. Barry KH, Martinsen JI, Alavanja MCR, Andreotti G, Blair A, Hansen J, et al. Risk of early-onset prostate cancer associated with occupation in the nordic countries. Eur J Cancer. 2017;87:92–100.
31. Pukkala E, Martinsen JI, Lynge E, Gunnarsdottir HK, Sparen P, Tryggvadottir L, et al. Occupation and cancer - follow-up of 15 million people in five nordic countries. Acta Oncol. 2009;48(5):646–790.
32. Bates MN. Registry-based case-control study of cancer in California firefighters. Am J Ind Med. 2007;50(5):339–44.
33. Tsai RJ, Luckhaupt SE, Schumacher P, Cress RD, Deapen DM, Calvert GM. Risk of cancer among firefighters in California, 1988–2007. Am J Ind Med. 2015;58(7):715–29.
34. Bigert C, Martinsen JI, Gustavsson P, Sparén P. Cancer incidence among Swedish firefighters: an extended follow-up of the NOCCA study. Int Arch Occup Environ Health. 2020;93(2):197–204.
35. Heikkinen S, Demers PA, Hansen J, Jakobsen J, Kjaerheim K, Lynge E, et al. Incidence of cancer among nordic Police officers. Int J Cancer. 2023;152(6):1124–36.
36. Barul C, Parent ME. Occupational exposure to polycyclic aromatic hydrocarbons and risk of prostate cancer. Environ Health. 2021;20(1):71.
37. Gandaglia G, Leni R, Bray F, Fleshner N, Freedland SJ, Kibel A, et al. Epidemiology and prevention of prostate Cancer. Eur Urol Oncol. 2021;4(6):877–92.
38. Teschke K, Olshan AF, Daniels JL, De Roos AJ, Parks CG, Schulz M, et al. Occupational exposure assessment in case-control studies: opportunities for improvement. Occup Environ Med. 2002;59(9):575–93. discussion 94.

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