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Cancer mortality and sectors of employment: a cohort study in Italy

Stefania Massari[1*], Lisa Bauleo[2], Claudio Gariazzo[1], Paola Michelozzi[3], Luca Dei Bardi[3,4,7,8], Nicolas Zengarini[5], Sara Maio[6], Massimo Stafoggia[3], Marina Davoli[3], Giovanni Viegi[6,9], Giulia Cesaroni[3], Alessandro Marinaccio[1] and on behalf of the BIGEPI Collaborative Group

Abstract

Background Cancer is a multifactorial disease. The large impact of occupational exposure on the burden of cancer continues to be a paramount public health concern that deserves more attention. The study aims to evaluate cancer-specific mortality risk in relation to sectors of employment.

Methods We used a cohort from the Rome Longitudinal Study (ROL) and linked it with the National Social Insurance Agency (INPS) database to obtain working histories. We considered the longest duration of employment in a sector as a proxy of exposure, and insurance activities as the reference category. A Cox regression adjusted model was used to examine the associations between cancer-specific causes of death and the sector of employment in men and women. A similar analysis was performed considering the length of employment (≤ 10 years versus ≥ 10 years).

Results The study population comprised 910,559 (52% of the total population of the cohort after linkage with INPS) 30+yr employees (53% men and 47% women) followed for a total period of approximately 7 million years. The outcomes confirmed some well-known associations (e.g. lung and pleura in construction, pleura in paper and printing, and lung in wood and leather) and suggested possible high-risk sectors that have not yet been thoroughly investigated. In men we observed an increased mortality risk for stomach cancer in the printing and paper industry (HR = 1.69, 95% CI:1.11–2.57) as well as for stomach and lung cancer in cleaning activities (HR = 1.98, 95% CI:1.13–3.49 and HR = 1.55, 95% CI:1.22–1.98, respectively). Among women, there was an elevated mortality risk in the cleaning industry for all malignant cancers (HR = 1.15, 95% CI:1.03–1.29), liver cancer (HR = 1.94, 95% CI:1.08–3.48) and cancer of the lympho-hematopoietic tissue (HR = 1.65, 95% CI:1.09–2.50).

Conclusions The results showed an increased risk of cancer death in some traditional industrial sectors compared to the reference category of insurance activities such as construction and wood and leather products and limited evidence in sectors like cleaning, accommodation and food services and hairdressing. The adopted method proved to be effective in monitoring occupational risks and activating proper prevention initiatives and further insights.

Keywords Work-related cancer, Administrative data, Hazard ratio, Occupational epidemiology, Routinely collected health data, Social security statistics

*Correspondence:
Stefania Massari
s.massari@inail.it
Full list of author information is available at the end of the article

Background

Cancer is a multifactorial disease, i.e. a combination of multiple factors, such as genetic, environmental, and lifestyle factors influences its development [1, 2]. The large impact of occupational exposure on the burden of cancer continues to be a paramount public health concern that deserves more attention. The World Health Organization (WHO) and International Labor Office (ILO) have recently produced estimates of the risks attributable to workplace exposure, concluding that occupational risks are undervalued as health determinants. In 2016, the two agencies estimated a total of 1.9 million deaths caused by occupational risk factors worldwide, with 80% due to diseases and 20% due to accidents [3]. The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD), aimed to understand the magnitude of the cancer burden attributable to behavioral, environmental, occupational, and metabolic risk factors. The estimated number of deaths due to occupational carcinogens was 333,500 worldwide, with percentages of 4.7% for men and 1.5% for women [4]. Lung cancer accounted for 86% of the deaths, mesothelioma for 7.9% and laryngeal cancer for 2.1%. Asbestos was responsible for the greatest number of deaths due to occupational carcinogens (63%); other important risk factors were secondhand smoke (14%), silica (14%) and diesel engine exhaust (5%) [5].

In the European Union, approximately 120,000 work-related cancer cases and 80,000 deaths are estimated annually due to exposure to carcinogens at work [6]. In Italy the burden of occupational cancer has been estimated to be approximately 8,000–8,500 deaths a year (84% men and 16% women) [7]. The estimates are far from the official numbers which amount to 217 cancer deaths out of 696 compensated professional cancers in 2022 [8]. These discrepancies may be explained by the difficulty in determining the occupational etiology and, consequently, in distinguishing between work-related and nonwork-related cancers. Only for occupational cancers with a high attributable fraction, it was possible to implement a collection method based on active research aimed at acquiring information about work activities and occupational exposures that may be responsible for neoplasia at the individual level such as the Italian National Mesothelioma Registry (ReNaM) and the Italian Sinonasal Cancer Registry (ReNaTuNS) [9].

For cancers that have a lower etiological fraction, improving epidemiological research methods to identify cancer onset and determine the etiological nature and intensity of historical exposure to carcinogens is essential.

There are multiple approaches to defining exposure that can be applied, such as industrial hygiene analysis, which is the most accurate, but it also requires considerable time and resources, self-reported assessment via interviews and a job exposure matrix [10–15].

A notable initiative by the Nordic countries, NOCCA, sought to explore the associations between occupations and cancer by linking census data (collecting occupation through self-administered questionnaires) and cancer registry data. This effort led to the creation of the Nordic Job Exposure Matrix, which converts work histories into quantitative exposure estimates [16].

In Italy, numerous studies have used record linkage methods to estimate the risk of cancer diagnosis and the permanence in a particular economic sector, considering the employment histories acquired from current data sources as a measure of exposure [17–19]. The use of such "electronic data linkages" has been demonstrated to be a powerful tool in epidemiological studies, such as case-control studies [18], mortality studies [19] and cohort studies [17].

In this study, we aimed to assess the association between cancer-specific mortality risk and employment in particular industrial sectors using an administrative cohort combined with working histories obtained from social security data.

Methods

Study design and data sources

We conducted this study within the BIGEPI project (Uso di BIG data per la valutazione degli effetti sanitari dell'inquinamento atmosferico nella popolazione italiana i.e., BIG data for investigating air pollution health effects in the population of Italy) [20].

The study population refers to the Rome Longitudinal Study (ROL), including the Roman residents who filled in the 2011 census questionnaire [21, 22], which has already been described elsewhere [17]. Briefly, each subject is followed from the census reference day (9th October 2011) to the 31st of December 2019, or the date of migration from Rome, or the date of death, whichever comes first. The entire cohort was linked with the National Social Insurance Agency (INPS) database to enrich the Rome Longitudinal Study with information on working history.

The INPS database contains individuals who have worked in private companies with at least one employee from 1974 onwards. This source covers approximately 55% of the Italian workforce and does not include data on public employees, self-employed workers, artisans, domestic workers, para-subordinate workers, and occasional workers.

The collected information refers to the occupational sectors from 1974 to 2011 (baseline) if the duration of employment was at least 1 year. The professional status of the workers was not available in the INPS database. The industrial sectors were classified according to the

Statistical Classification of Economic Activities in the European Community, NACE Rev. 2, and were grouped into 25 broader categories [23].

Data access was granted by the National Statistics Program (PSN 2020–2022), which provides prior authorization with the force of law of the Italian Data Protection Authority for statistical works of public interest. The linkage between the Rome Longitudinal Study and the INPS files was made at the individual level on the basis of tax ID codes according to the National Statistical Program, which is approved annually by the Italian Data Protection Authority [24]. The resulting dataset is produced with anonymized identifiers.

Study population

The linkage procedure between the Rome Longitudinal Study and INPS data was effective in identifying approximately 52% of the original cohort, consisting of 1,739,277 individuals with complete and valid data. The coverage of the Italian workforce provided by the INPS archive is limited to workers employed in private industry, corresponding to approximately55% of the workforce. Public employees (e.g., ministries, regions, municipalities, armed forces, public schools and universities and public healthcare) are excluded. The study population included all residents aged 30 + years who had worked, for at least one year, in one of the private economic sectors listed in the INPS files and amount to 910,559 subjects (53% men). A detailed description of the cohort is reported elsewhere [17] and a flow chart of the study population is shown in Figure S1 of the Supplementary Materials (SM). The study is performed for neoplasm mortality classified into 20 cancer sites according to the International Classification of Diseases (ICD-9), codes 140–208 [25].

Statistical analyses

We calculated the person-time at risk for each subject during the study period, i.e. from the 9th of October 2011 to the date of migration from Rome, or the date of death, or the 31st of December 2019, whichever came first. For men and women separately, we calculated the age-standardized mortality rates (per 10,000) with 95% confidence intervals (95% CI) for each employment sector, using the 2011 Italian population as the standard population. We analyzed, as the main analysis, the associations between the sector of employment and cancer-specific causes of death in men and women through Cox regression models with age as the time scale producing hazard ratios (HRs) and 95% CI. We deemed the employment sector as a proxy of exposure, considering the sector with the longest duration throughout an individual's working life (referred to as the lifetime prevalent sector), and utilized insurance activities as the reference category because it includes a significant number of white-collar workers and has the lowest age-standardized mortality rates compared with other categories, as demonstrated in Bauleo [17].

We considered, as adjustment variables, the variables available from the 2011 census such as level of education (classified as high, university; medium, high school; low, primary and junior high school), place of birth (Rome, Lazio Region, Northern Italy, Central Italy, Southern and Insular Italy, other countries), and marital status (single, married, separated or divorced, widowed). Place of birth, marital status and education level were deemed as proxies for socioeconomic status, and gender was used as a stratification variable.

We performed a sensitivity analysis to assess the hypothesis that a longer employment duration may produce a higher risk of dying from an occupation-related cancer. To do so, we replicated the main analyses using a stratification by length of employment ($\leq$ 10 years versus > 10 years).

Finally, we repeated the analysis to assess any changes in the estimate of HRs using the administrative and support service activities as the reference category, as it has lower age-standardized mortality rates for women compared to other sectors.

Results

Characteristics of the study population

The study population comprised 910,559 employees in the private sector aged more than 30 years (53% men and 47% women) followed by a total of approximately 7 million person-years.

Table 1 shows the characteristics of the cohort by prevalent employment sector; the number of workers, the person-years of follow-up, the number of deaths during the follow-up and the age-standardized mortality rates per 10,000 for cancer mortality in men and women. The most frequent sectors of employment among enrolled individuals, for both genders, are administrative and support service activities, wholesale and retail trade, insurance activities and transportation and storage, which mirror the prevailing service-oriented economy of the city. There is a slight prevalence of women in healthcare, washing and dry-cleaning of textiles, wholesale and retail trade and agriculture, as well as a predominance of men in the manufacturing of basic metals, construction and transportation. Cancer deaths are totally 23,515 (M:68% F:32%), with a prevalence in administrative and support activities for both genders as well as in transport and construction for men only.

Figure 1 shows box whisker plots with the median and interquartile range of the duration of employment for men and women by sector. The distribution differs

Table 1 Characteristics of the study population, number of subjects (N), person-years (PY), number of cancer deaths (ICD9 140-208) and age-standardized mortality rates (CMR per 10,000) by prevalent sector of employment (NACE Rev.2) and gender. Rome Longitudinal Study 2011-2019

Sector of employment	Men				Women			
	N	PY	Cancer deaths	CMR(per 10,000) (95% CI)	N	PY	Cancer deaths	CMR (per 10,000) (95% CI)
Total	478,199	3,663,919	15,932	297 (292-303)	432,360	3,399,940	7,583	171 (167-176)
Agriculture, Forestry, Hunting and Fishing (01-03)	11,810	74,238	788	315 (286-347)	23,588	155,037	881	145 (131-161)
Mining and quarrying (05-09)	514	3,365	29	268 (185-387)	189	1,300	5	182 (63-528)
Manufacture of food and tobacco products (10-12)	7,653	50,250	313	346 (303-397)	4,211	29,037	65	193 (145-257)
Manufacture of made-up textile articles and wearing apparel (13-14)	2,249	14,595	85	297 (222-396)	7,738	53,091	148	150 (123-181)
Manufacture of wood and leather products (15-16)	4,551	29,678	224	359 (308-420)	1,722	11,852	24	159 (87-290)
Manufacture of machinery for paper and Printing (17-18)	13,014	85,932	580	323 (291-358)	8,379	57,458	171	183 (150-223)
Manufacture of chemicals, pharmaceutical and rubber products (19-22)	12,123	79,876	482	289 (259-322)	8,041	55,288	149	177 (145-215)
Manufacture of glass and ceramic products (23)	700	4,514	26	283 (184-438)	263	1,789	8	280 (116-674)
Manufacture of basic metals and machining (24, 28-30)	44,505	301,881	940	313 (287-342)	18,507	128,732	163	160 (127-202)
Treatment and coating of metals (25.61)	285	1,891	8	285 (138-588)	71	497	1	82 (12-582)
Manufacture of electrical equipment (27)	15,908	107,336	502	265 (239-294)	6,597	45,301	165	203 (169-244)
Other manufacturing (25 except 25.61,26.31-33)	6,763	44,836	250	303 (264-349)	4,671	32,162	82	183 (134-251)
Electricity, gas, steam and air conditioning supply and sewerage (35)	5,547	36,850	201	251 (215-292)	2,666	18,427	50	205 (148-284)
Waste collection (38-39)	1,185	8,096	21	342 (193-607)	655	4,562	5	107 (27-422)
Construction (41-43)	52,837	346,164	2,240	344 (329-361)	8,616	59,575	127	163 (128-206)
Wholesale and retail trade (45-47 except 47.30)	65,687	441,432	1,734	302 (285-320)	78,107	539,938	987	181 (165-199)
Retail sale of automotive fuel (47.30)	1,256	8,395	16	143 (85-238)	162	1,097	1	161 (23-1142)
Transportation and storage (49-53)	68,160	456,417	2,451	285 (271-300)	21,531	148,896	331	200 (164-245)
Accommodation and food service activities (55-56)	28,250	187,597	772	322 (296-350)	18,967	128,478	281	189 (164-219)
Administrative and support service activities (58-99, except 96.01, 96.02, 81.2)	55,984	369,432	2,252	273 (260-287)	94,417	645,419	2,120	167 (159-176)
Cleaning activities (81.2)	9,149	61,532	217	382 (316-462)	26,203	178,552	580	203 (183-224)
Human health and social work activities (86-88)	7,528	50,962	203	344 (284-416)	24,801	170,143	400	172 (154-192)
Washing and dry-cleaning of textile (96.01)	833	5,514	31	362 (239-549)	1,598	11,055	20	154 (80-295)
Hairdressing (96.02)	1,568	10,578	38	303 (205-449)	6,249	43,507	53	213 (135-302)
Insurance activities (65)	60,140	404,576	1,529	269 (252-287)	64,411	446,554	766	192 (172-214)

among sectors, but is quite similar in both genders, positively skewed, with a length of employment showing a median value of 9 years and standard deviation of 9.50 (11 for men dev-std:9.86 and 8 for women and dev-std:8.86), and a dispersion slightly higher in men than in women.

The age-standardized mortality rates with 95% CI by sector and gender are illustrated in Fig. 2 and reported in detail in Table 1. The age-standardized mortality rates (per 10,000) for the sector of insurance activities, considered as a reference in this study, are 269 (per 10,000) (95% CI: 252–287) for men and 192 (per 10,000) (95% CI:

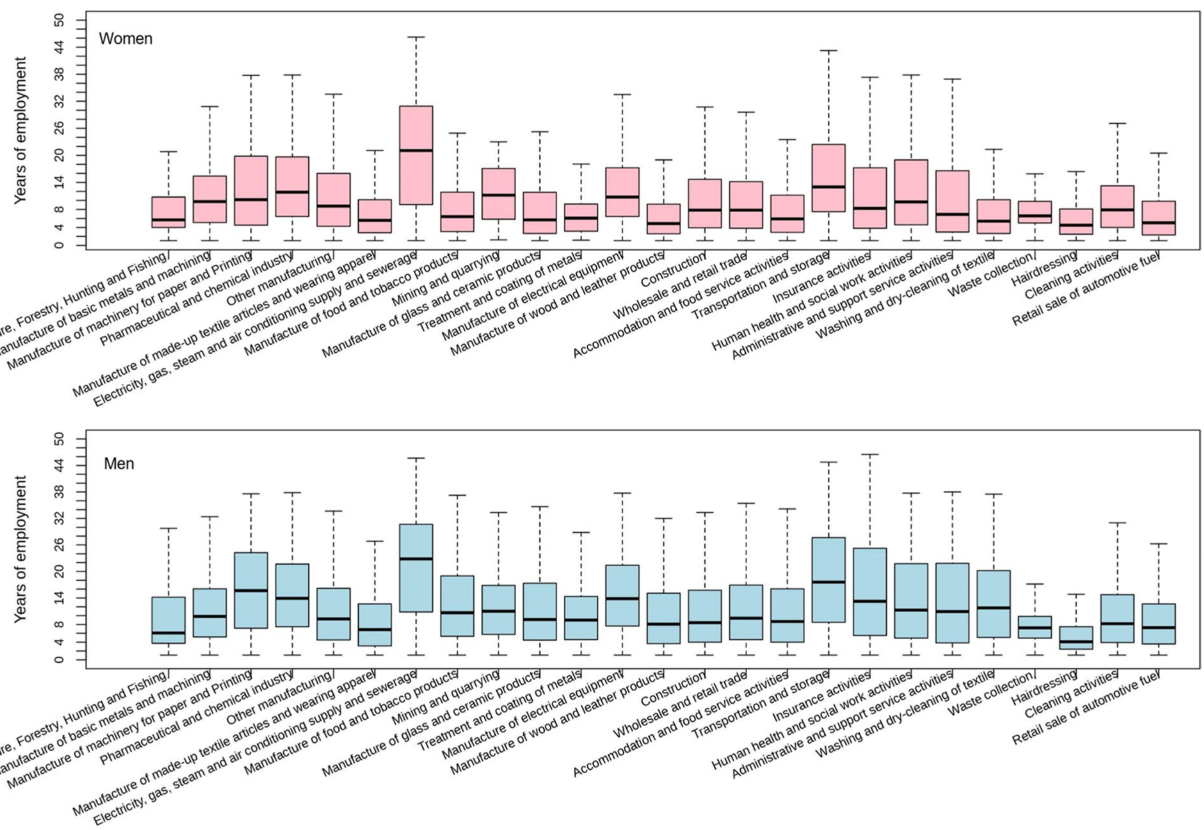

Fig. 1 Duration of employment (in years) by sector and gender. Rome 2011–2019

172–214) for women. In men, the sectors characterized by higher mortality than insurance activities are cleaning activities, washing and dry-cleaning of textile, wood and leather products, food and tobacco, construction and human health and social work activities. In women, the sectors with higher mortality rates than insurance activities supported by a consistent numerosity are cleaning activities, hairdressing, manufacturing of electrical equipment, electricity, gas, steam and air conditioning supplies and sewerage. The ceramic industry was not deemed significant, as it had a high mortality rate but accounted for only 8 cancer-related deaths.

Hazard ratio by malignant cancer and sector of employment

Tables 2 and 3 show the results of the associations between industrial sectors and neoplastic causes of death by gender. This analysis includes the adjusted hazard ratios (HRs) for the main analysis and the sensitivity analysis considering the length of employment. For the sake of brevity, a selection of HRs is presented below. All the significant results are reported in Table S1 of the Supplementary Materials.

Among men (Table 2), the highest risks for all malignant cancers were observed for workers in washing and dry cleaning of textile, human health and social work activities, cleaning activities, construction, accommodation and food service activities, manufacturing of food and tobacco products, manufacturing of wood and leather products, and the wholesale and retail trade. For specific neoplastic sites, we observed an increased risk for trachea, bronchus and lung cancer in construction (HR = 1.27, 95% CI:1.12–1.44) and in accommodation and food service activities (HR = 1.26, 95% CI:1.07–1.48), cleaning activities (HR = 1.55, 95% CI:1.22–1.98) and healthcare (HR = 1.51, 95% CI:1.17–1.97); for pleura cancer in construction (HR = 3.46, 95% CI:1.37–8.69), for prostate in the manufacture of wood and leather products (HR = 1.82, 95% CI:1.15–2.88) and in the manufacture of electrical equipment (HR = 1.48, 95% CI:1.05–2.08). An increased risk for the central nervous system, as well as for brain cancer, was observed in the manufacture of basic metals and machining (HR = 1.52, 95% CI:1.10–2.31; HR = 1.56, 95% CI:1.02–2.39, respectively) and construction (HR = 1.54, 95% CI:1.04–2.29; HR = 1.55, 95% CI:1.03–2.34, respectively). Finally, cleaning activities resulted in an increased risk of stomach and

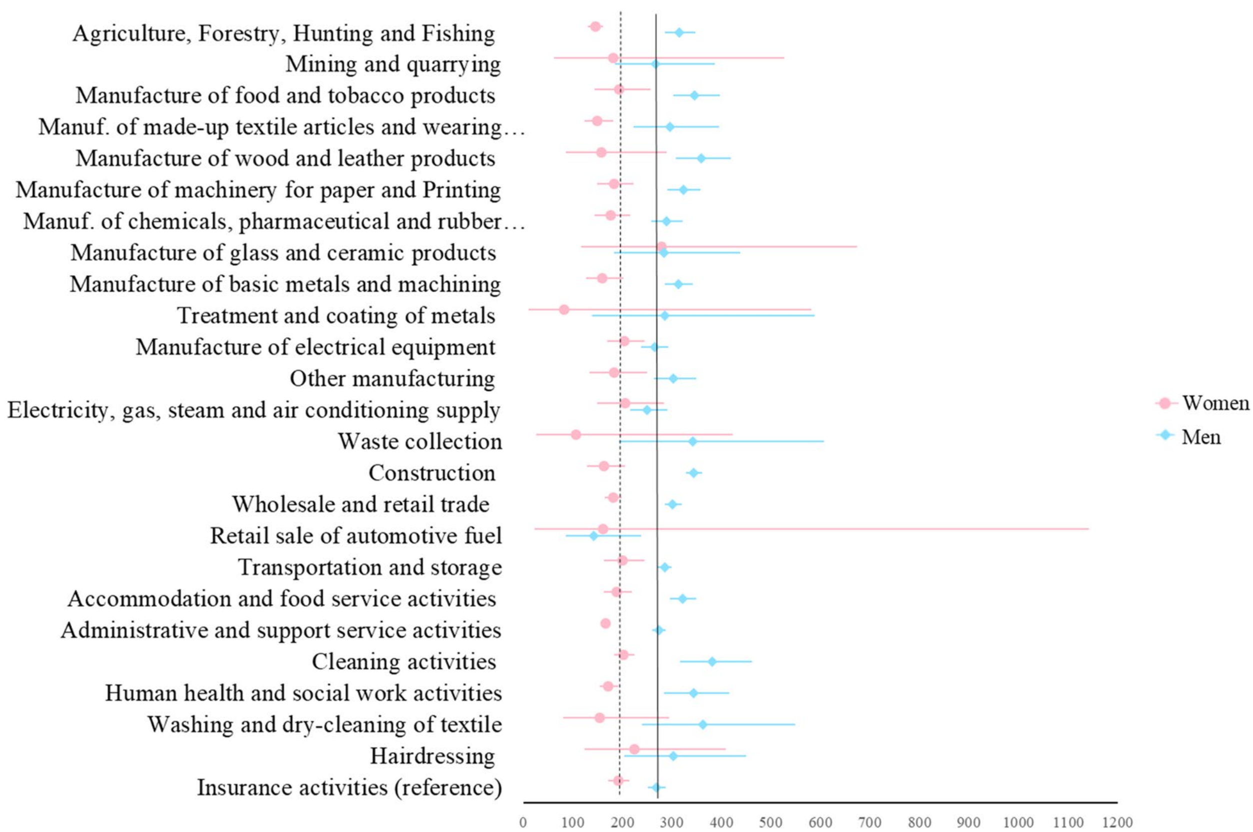

Fig. 2 Age-standardized mortality rates (per 10,000) for cancer mortality (ICD9 140–208) by sector and gender (vertical lines refer to age-standardized mortality rates in insurance activities, dashed for women and continuous for men; dots for women and diamonds for men). Rome 2011–2019

lung cancers (HR = 1.98, 95% CI:1.13–3.49 and HR = 1.55, 95% CI:1.22–1.98, respectively) and hairdressing in an increased risk of liver cancer (HR = 2.48, 95% CI:1.14–5.40) albeit in a smaller cluster.

Among women (Table 3), the cleaning industry was associated with an increased risk of mortality for all malignant cancers (HR = 1.15, 95% CI:1.03–1.29), liver cancer (HR = 1.94, 95% CI:1.08–3.48) and cancers of lympho-hematopoietic tissue (HR = 1.65, 95% CI:1.09–2.50). Notably, there are excess risks of mortality for liver in the chemical industry (HR = 2.29, 95% CI:1.12–4.68), for lympho-hematopoietic tissue in transport (HR = 1.59, 95% CI:1.00–2.52) and in health services (HR = 1.68, 95% CI:1.10–2.56) and for leukemia in agriculture (HR = 2.03, 95% CI:1.12–3.71).

The results of sensitivity analyses for length of employment are shown in Tables 2 and 3 for men and women, respectively. For men, we find different results depending on both outcome and sector. Long-term employment in a sector was positively associated with mortality for all malignant cancers in the manufacturing of food and tobacco products, accommodation and food service activities, cleaning activities and washing and dry-cleaning of textile. A similar relationship was found for the following associations of the cancer site and industrial sector: the stomach in the sector of the manufacture of machinery for paper and printing, accommodation and food service activities, and cleaning activities; liver cancer in the hairdressing sector; and the central nervous system and brain cancer in the manufacture of basic metals and machining and construction. Conversely for lung cancer, the effect of length of employment seems to indicate a higher risk for workers employed for less than 10 years, except for workers in cleaning activities.

Among women, higher HRs were reported for persons working longer than 10 years for all malignant cancers and liver cancer in cleaning activities, for lympho-hematopoietic tissue cancer in transport, human health and social work activities and for leukemia in agriculture.

The results of the sensitivity analysis, which used administrative and support service activities as the reference category, revealed no significant differences in male hazard ratios (HRs) and identified new associations in female HRs as follows: an increased mortality risk

Table 2 Association between cause-specific mortality and sectors of employment. Hazard ratios (HRs) and 95% confidence intervals (CIs) from Cox regression analysis adjusted for age, level of education, place of birth and marital status, with insurance activities used as the reference category. Rome Longitudinal Study 2011-2019. (Men)

Cause of death (ICD-9 codes)	Sectors of employment (NACE code)	Main Analysis[a]		Analysis by duration of employment > 10 years		Analysis by duration of employment ≤ 10 years	
		Deaths	HR (95% CI)	Deaths	HR (95% CI)	Deaths	HR (95% CI)
Malignant cancer (140–239)	Manufacture of food and tobacco products (10–12)	313	1.17 (1.04–1.33)	213	1.22 (1.05–1.42)	100	1.05 (0.83–1.32)
	Manufacture of wood and leather products (15–16)	224	1.17 (1.02–1.35)	109	1.09 (0.89–1.33)	115	1.18 (0.95–1.47)
	Other manufacturing (25 except 25.61,26,31–33)	250	1.14 (1.10–1.30)	140	1.12 (0.94–1.34)	110	1.09 (0.88–1.37)
	Construction (41–43)	2,240	1.21 (1.13–1.30)	1,252	1.18 (1.08–1.28)	988	1.20 (1.04–1.37)
	Wholesale and retail trade (45–47 except 47.30)	1,734	1.10 (1.02–1.18)	999	1.04 (0.96–1.13)	735	1.15 (1.00–1.32)
	Accommodation and food service activities (55–56)	772	1.18 (1.08–1.29)	519	1.23 (1.10–1.36)	253	1.05 (0.88–1.25)
	Human health and social work activities (86–88)	203	1.28 (1.11–1.49)	148	1.27 (1.07–1.51)	55	1.27 (0.95–1.70)
	Cleaning activities (81.2)	217	1.26 (1.09–1.45)	133	1.28 (1.07–1.53)	84	1.19 (0.93–1.53)
	Washing and dry-cleaning of textile (96.01)	31	1.33 (0.93–1.90)	26	1.64 (1.11–2.43)	5	0.64 (0.26–1.55)
Stomach (151)	Manufacture of machinery for paper and Printing (17–18)	37	1.69 (1.11–2.57)	26	1.71 (1.05–2.79)	11	1.64 (0.70–3.81)
	Construction (41–43)	125	1.49 (1.08–2.06)	66	1.38 (0.93–2.03)	59	1.55 (0.80–3.02)
	Accommodation and food service activities (55–56)	51	1.65 (1.12–2.44)	38	1.94 (1.25–3.03)	13	1.15 (0.51–2.60)
	Cleaning activities (81.2)	16	1.98 (1.13–3.49)	10	1.99 (0.99–3.98)	6	1.85 (0.67–5.10)
Colon and rectum (153–154, 159)	Manufacture of wood and leather products (15–16)	34	1.61 (1.11–2.35)	17	1.59 (0.95–2.64)	17	1.46 (0.81–2.63)
Liver (155–156)	Construction (41–43)	156	1.33 (1.02–1.74)	87	1.30 (0.94–1.79)	69	1.47 (0.81–2.64)
	Hairdressing (96.02)	7	2.48 (1.14–5.40)	4	6.3 (2.28–17.41)	3	1.26 (0.36–4.47)
Trachea, bronchus and lung (162)	Manufacture of food and tobacco products (10–12)	110	1.41 (1.14–1.74)	74	1.40 (1.09–1.81)	36	1.44 (0.95–2.17)
	Manufacture of wood and leather products (15–16)	68	1.18 (0.91–1.52)	27	0.87 (0.59–1.29)	41	1.50 (1.01–2.23)
	Manufacture of electrical equipment (27)	157	1.07 (0.89–1.28)	107	0.96 (0.77–1.19)	50	1.45 (1.00–2.11)
	Construction (41–43)	670	1.27 (1.12–1.44)	383	1.22 (1.05–1.41)	287	1.34 (1.02–1.77)
	Wholesale and retail trade (45–47 except 47.30)	541	1.17 (1.03–1.33)	326	1.12 (0.96–1.30)	215	1.27 (0.95–1.68)
	Accommodation and food service activities (55–56)	237	1.26 (1.07–1.48)	157	1.24 (1.02–1.50)	80	1.29 (0.92–1.80)
	Human health and social work activities (86–88)	66	1.51 (1.17–1.97)	50	1.52 (1.13–2.04)	16	1.51 (0.87–2.62)
	Cleaning activities (81.2)	80	1.55 (1.22–1.98)	53	1.64 (1.22–2.20)	27	1.47 (0.93–2.32)
Pleura (163)	Manufacture of machinery for paper and Printing (17–18)	7	3.26 (1.08–9.85)	5	3.76 (0.99–14.38)	2	1.79 (0.25–12.97)
	Electricity, gas, steam and air conditioning supply and sewerage (35)	5	5.68 (1.72–18.77)	4	5.52 (1.35–22.49)	1	8.67 (0.72–103.76)
	Construction (41–43)	25	3.46 (1.37–8.69)	14	3.54 (1.12–11.17)	11	1.98 (0.42–9.42)
Prostate (185)	Manufacture of electrical equipment (27)	49	1.48 (1.05–2.08)	38	1.65 (1.12–2.44)	11	1.01 (0.48–2.09)
	Manufacture of wood and leather products (15–16)	23	1.82 (1.15–2.88)	9	1.35 (0.67–2.72)	14	2.26 (1.13–4.49)

Table 2 (continued)

Cause of death (ICD-9 codes)	Sectors of employment (NACE code)	Main Analysis[a]		Analysis by duration of employment > 10 years		Analysis by duration of employment ≤ 10 years	
		Deaths	HR (95% CI)	Deaths	HR (95% CI)	Deaths	HR (95% CI)
Bladder (188)	Wholesale and retail trade (45–47 except 47.30)	91	1.19 (0.86–1.64)	51	0.97 (0.66–1.42)	40	2.70 (1.13–6.44)
	Transportation and storage (49–53)	113	0.95 (0.69–1.29)	81	0.77 (0.55–1.09)	32	2.79 (1.15–6.78)
Central nervous system (191,192,225)	Manufacture of basic metals and machining (24, 28–30)	43	1.52 (1.10 2.31)	31	1.88 (1.15–3.07)	12	0.92 (0.41–2.06)
	Construction (41–43)	60	1.54 (1.04–2.29)	38	1.72 (1.07–2.78)	22	1.18 (0.57–2.44)
Brain (191)	Manufacture of basic metals and machining (24, 28–30)	42	1.56 (1.02–2.39)	30	1.89 (1.14–3.12)	12	1.01 (0.44–2.30)
	Construction (41–43)	54	1.55 (1.03–2.34)	35	1.76 (1.07–2.88)	19	1.18 (0.55–2.54)

[a] Results refer to HRs statistically significant with $N > 5$ for the main analysis

Table 3 Association between cause-specific mortality and sectors of employment. Hazard ratios (HRs) and 95% confidence intervals (CIs) from Cox regression analysis adjusted for age, level of education, place of birth and marital status, with insurance activities used as the reference category. Rome Longitudinal Study 2011–2019. (Women)

Cause of death (ICD-9 codes)	Sectors of employment (NACE code)	Main Analysis[a]		Analysis by duration of employment > 10 years		Analysis by duration of employment ≤ 10 years	
		Deaths	HR (95% CI)	Deaths	HR (95% CI)	Deaths	HR (95% CI)
Malignant cancer (140–208)	Cleaning activities (81.2)	580	1.15 (1.03–1.29)	304	1.24 (1.06–1.44)	276	1.06 (0.90–1.26)
Liver (155–156)	Manufacture of chemicals, pharmaceutical and rubber products (19–22)	12	2.29 (1.12–4.68)	3	0.96 (0.27–3.43)	9	4.65 (1.8–12.01)
	Human health and social work activities (86–88)	24	1.88 (1.04–3.43)	12	1.62 (0.71–3.7))	12	2.36 (0.98–5.70)
	Cleaning activities (81.2)	30	1.94 (1.08–3.48)	14	2.01 (0.89–4.53)	16	1.80 (0.77–4.21)
Trachea, bronchus and lung (162)	Other manufacturing (25 except 25.61,26,31–33)	31	1.66 (1.13–2.45)	18	1.69 (1.02–2.81)	13	1.59 (0.87–2.91)
Lymphatic and haematopoietic tissue (200–208)	Transportation and storage (49–53)	31	1.59 (1.00–2.52)	24	1.74 (0.99–3.04)	7	1.36 (0.57–3.25)
	Human health and social work activities (86–88)	44	1.68 (1.10.2.56)	31	1.94 (1.13–3.31)	13	1.29 (0.63–2.65)
	Cleaning activities (81.2)	52	1.65 (1.09–2.50)	23	1.52 (0.85–2.74)	29	1.80 (0.98–3.29)
Leukemia (204–208)	Agriculture, Forestry, Hunting and Fishing (01–03)	53	2.03 (1.12–3.71)	12	2.33 (0.85–6.39)	41	1.43 (0.65–3.14)

[a] Results refer to HRs statistically significant with $N > 5$ for the main analysis

for lung cancer in machinery manufacturing, paper and printing, accommodation and food service activities, and cleaning activities; for ovarian cancer in transportation and storage; and for pancreatic cancer in transportation and storage, wholesale, and hairdressing. The significant results are reported in Table S2 and Table S3 of the Supplementary Materials.

Discussion

The study, characterized by high statistical power, enabled the investigation of excess mortality risks in 25 industrial sectors and 20 causes of cancer in men and women and consequently the identification of higher-risk groups of workers for specific types of cancer in sectors of employment.

Identification of risk factors is difficult since the occurrence of cancer diagnosis depends on multiple factors, and there is little distinction between professional and environmental factors. The delay between exposure and clinical diagnosis, particularly for solid tumors, may last for decades, which makes it difficult to identify occupational or other factors that could contribute to the onset of the pathology.

Understanding etiology requires a comprehensive assessment of micro-exposures and potential interactions among multiple hazardous agents, often leading to additive or synergistic effects. The most effective way to assess occupational exposure would be to have an expert industrial hygienist who analyzes individual job descriptions. Although this method produces accurate results, it is time-consuming, costly, and challenging to be implemented in large-scale studies. A valid method to gather occupational information retrospectively for epidemiological research is collecting complete employment histories through administrative records [14].

Known associations with work-related cancer risk

The study identified well-known cancer-risk sectors, such as construction, food and tobacco products, other manufacturing and wood and leather products. In particular, we found a positive association in construction workers for lung and pleura cancer, a well-known risk [26], which has been reduced in the last 20 years owing to strong regulations to reduce exposure to asbestos and silica [27].

In the food industry, an excess risk for respiratory neoplasms is well documented considering an association with biological agents (oncogenic viruses), fumes emitted during the smoking of meat, aerosols emitted during frying/cooking of meat, and nitrosamines and other chemicals present in spices, or formed or used during the curing of meat [28].

Tobacco manufacturing has shown to be positively associated with lung cancer likely attributed to the exposure to foliar residues of pesticides or to asbestos [29, 30].

A positive association was also found in wood and leather production for all neoplasms and, in particular, for the colon-rectum, lung and prostate. The International Agency for Research on Cancer (IARC) has provided sufficient evidence for lung cancer from exposure to arsenic and chrome but limited evidence for prostate and colon with the exposure to arsenic and asbestos [31, 32]. The significant excess risks of mortality found for prostate cancer in the leather industry were in line with the scientific literature only partially on the basis of incidence data [33].

New associations with limited evidence

For the new associations with limited evidence, we found sectors of activities likely associated with exposure to potential carcinogens, including the manufacture of paper and printing products, cleaning, accommodation and food service activities and hairdressing.

A statistically significant increased risk of stomach cancer mortality in the printing and paper industry was reported in 44 cases (37 males and 7 females) (HR = 1.69, 95% CI:1.11–2.57). IARC has identified such risk with limited evidence associating it with lead and its compounds (e.g. lead dioxide, tetraoxide, sulfide, chromate, and dinitrate) used during the printing process, such as a dye or a coating for paper used in photothermography [34]. In this sector we found an increased risk for pleura cancer, likely ascribed to asbestos exposure but since such results are based on 11 cases, caution should be taken, as the findings are not supported by the literature.

For the cleaning sector, we found an increased mortality risk for all cancers and specifically for stomach and lung cancer in men and for liver and lympho-haematopoietic cancer in women. Cleaning workers are exposed to chemical substances that are found in dirt and dust while being removed from surfaces, floors, furniture, etc [35]. The main active components of most cleaning agents responsible for health damage are surfactants, acids or bases, disinfectants, solvents, or some complexing agents (substances capable of forming a complex compound with another material in solution) [36]. Additionally, formaldehyde is used in some cleaning products as a disinfectant or preserving agent and cleaners may also be exposed to volatile organic compounds (VOCs) emanating from cleaning products [37]. Cleaners, in the past, were found to be affected mainly by musculoskeletal diseases, skin diseases, dermatitis, and respiratory, circulatory and cardiovascular disorders [38]. In our study, cleaning workers reported an increased mortality risk of stomach and lung cancer in men and of liver and lympho-haematopoietic cancer in women. These results were partially confirmed by scientific literature that evidenced significant standardized mortality rates in patients with lung cancer [39], non-Hodgkin's lymphoma [40, 41], chronic lymphocytic leukemia [42] and leukemia [43]. The observed positive associations with stomach cancer in men and liver cancer in women are not supported by the literature. Moreover, these results are based on 16 and 30 cases respectively and should be interpreted with caution. Additionally, we cannot rule out the possibility that these associations may be influenced by lifestyle factors (e.g. smoking and alcohol consumption) rather than occupational exposure.

For workers in the restaurant and food preparation and cooking sector, we found an increased risk of mortality for stomach and lung cancer with 51 and 237 cases respectively. The cleaning and disinfecting chemicals substances along with cooking fumes and vapours are potential hazards [44]. A critical review showed that the consumption of repeatedly heated cooking oils and the inhalation of their fumes in association with exposure to polycyclic aromatic hydrocarbons (PAHs) could cause a high incidence of various cancers, including lung cancer [45]. The association with malignant neoplasms of digestive organs in restaurant workers is less documented in the literature; only a Spanish case-control study, carried out in 2012, found a statistically significant increased risk of stomach cancer in cooks [46]. A national mortality case-control study carried out among workers involved in restaurant activities reported a significant risk of lung cancer, supporting the findings of this study [47]. Lifestyle and alcohol consumption could also be considered additional risk factors for this association; consequently, our findings must be considered with caution.

Our study results revealed an increased risk of liver cancer among male hairdressers, which is consistent with the IARC classification of several substances commonly used in this profession, including hair colourants, hair dyes, hairsprays, formaldehyde, and certain solvents, as probable carcinogens [48, 49]. Such findings should prompt us to question the dangers of permanent hair colours, as they are not applied only by professionals but also by consumers, even if the frequency and duration of exposure, however, may be quite different for consumers and professionals. However, such risk should be considered with caution as the result is based on only seven cases in men, in the main analysis.

No concrete evidence supports the risk reported in our study for liver and stomach cancer in the construction industry, or for central nervous system and brain cancer, with the exception of a Canadian study that suggested a possible role of occupational exposure in the etiology of brain cancer in construction workers, particularly related to asbestos exposure [50]. Our results are supported by an adequate number of cases (60 for central nervous system and 54 for brain cancer) and show a statistically significant risk with a narrow confidence interval, indicating reliable results. However, it is difficult to propose specific etiological factors within these sectors that could explain the observed effects on brain health, highlighting the need for further studies.

In addition, the identified risk of the central nervous system and brain cancer detected in metallurgy is not in line with the scientific literature.

Discussion by length of employment

An analysis was performed to examine the association between the cancer site and industrial sector considering the duration of employment under study and a threshold of 10 years was used to create two groups according to the length of employment. The analysis yielded conflicting results that did not align with our expectation of increased risk associated with longer employment duration. In fact, for many of the outcomes and/or sectors the results do not show the expected increase in risk for individuals who have worked for more than 10 years compared with those with lower permanence in the sector. Consequently, we cannot conclude that higher risks are associated with a longer duration of employment since the results do not show significant differences. Possible explanations for this lack of evidence can be highlighted. First, our data suffer from left truncation, as occupational data are available only after 1974. This exclusion may have resulted in a loss of years of exposure, especially in our cohort where the mean age was above 50 years old. Moreover, we should emphasize that we have information on employment and not on exposure, and results show that the duration of employment may not be the correct information for estimating the level of exposure, as working conditions might have changed during the study period.

Another important methodological aspect to consider is the length of follow-up (2011–2019), which may not be enough to fully capture the long-term latency effects between occupational carcinogen exposure and cancer onset, particularly for solid tumours which can take decades to manifest. Previous studies suggest that latency periods of approximately 10 years are common for many solid cancers associated with occupational exposure [51]. This temporal limitation may have influenced our results, especially in sectors where exposure to potential carcinogens began many years before the follow-up period.

However, even with due caution, we highlight interesting differences in excess cancer risk mortality in industrial sectors with shorter durations that would be useful to deepen such as liver in hairdressing, all neoplasm, stomach and lung cancer in cleaning activities for men, and all neoplasms and liver cancer in cleaning activities for women. These work sectors often receive little attention because they are not traditionally considered high-risk.

A deeper analysis should also consider the use of lagged models that account for a longer latency period. In addition, the model should consider the working period to assess any potential changes resulting from the modernization of production processes.

Discussion by gender

As expected, gender differences in occupational cancer mortality have been observed and are well documented. These differences may be due to variations in workforce numbers or to the fact that men and women are employed in different sectors and/or occupations and are therefore exposed to different risk factors [52]. The percentages of women and men in the cohort were approximately 47% and 53% respectively, similar to the Italian workforce distribution. The sectors with a high prevalence of women are agriculture, textile and wearing apparel, wholesale, insurance, healthcare, administrative and support services, washing and dry cleaning, hairdressing, and cleaning activities. The results of the present study revealed an increased mortality risk in both genders for all neoplasms in cleaning activities. Excess mortality risks were observed among women in certain occupations: liver and lympho-hematopoietic cancers in cleaning activities, leukemia in agriculture, liver cancer in chemical, pharmaceutical, and rubber industries, and lympho-hematopoietic cancers in the transport and healthcare sectors. Among women, the increased mortality risk for lympho-hematopoietic cancers in the transport and healthcare sectors, as well as leukemia in agriculture, is particularly notable. Scientific evidence supports the association between leukaemia and agricultural work [53]. In transport, similar results have been observed among female truck and conveyor operators particularly for non-Hodgkin's lymphomas and myeloma [54, 55]. In healthcare personnel, the excess risk may be linked to exposure to formaldehyde or ethylene oxide.

A positive association was found among men in the construction sector for liver, trachea, bronchus and lung cancer, pleura, central nervous system and brain. An increased mortality risk was also observed in the construction sector for all cancers, and, in particular, for pleura, lung, liver, stomach, central nervous system and brain cancers.

We found discrepancies in leukemia risk between genders in the agricultural sector. In contrast to the expected risk of leukemia in males due to exposure to pesticides, we found a greater risk in females and a null association for males. Such results may be attributed to the "healthy worker" effect or to certain personal habits that increase the likelihood of cancer in women.

A gender-related discrepancy in excess mortality risk for leukemia has been identified within the agricultural sector. The evidence suggests that occupational mortality risk is influenced by gender-specific factors, including lifestyle, biological susceptibility, and behavioral differences. Generally, men have a greater overall risk of cancer. Notably, an Italian study reported an elevated risk of leukemia among female farmers compared with male farmers [56] which was confirmed by Waggoner et al. [57]. However, these results should be interpreted cautiously, as the number of studies that thoroughly analyze occupational cancer risk in women remains limited [58].

The sensitivity analysis using different reference categories for men and women, also, emphasized the need for gender-specific assessments of mortality risk. This finding underscores the importance of tailoring cancer prevention strategies to account for sex-based differences.

Limits and strengths

One of the most significant limitations of this study is the absence of direct exposure measurements. The approach used has the advantage of identifying higher-risk groups of workers but has the limitation of not pointing directly to specific etiologic factors, because of the lack of data on the type and level of occupational exposure. However, we address this by considering the industrial sector and the duration of employment as recorded in social security data. The maximum length of work in each sector was used as a proxy for exposure, although information on specific occupations, and its specific exposure, could not be included due to its unavailability in INPS records. Another limitation of the INPS data is the lack of information on occupation.

A further significant limitation of this study is the lack of direct information on individual confounders and lifestyle. This is particularly relevant for certain types of cancer (e.g. lung) in which data on smoking and alcohol consumption habits are strong confounders. There are studies in the literature attempting to address this issue by using sophisticated methodologies, but they are not suitable for occupational epidemiological studies [59]. To mitigate this bias, we used available covariates such as educational attainment as surrogates for smoking habits, given the well-known association between smoking and low educational attainment [60].

The loss to follow-up due to migration may cause skewed estimates in cohort studies. It mainly concerns young generations, particularly males in search of better work opportunities. Since our study population included mostly middle-aged people, we believe that the impact of migration on study outcomes would be minimal.

We acknowledge that the results may be limited since the study focused on mortality data. A future approach could be to replicate the study at national level using incidence data, if privacy restrictions allow.

Conclusion

The study concludes that working in specific industrial sectors significantly influences cancer mortality rates among workers in Italy, including traditional sectors such as construction and wood and leather products, as well as unexpected sectors such as accommodation services and hairdressing.

The adopted method enables straightforward and cost-effective identification of employment sectors with elevated cancer mortality risk. Using administrative work histories of individuals enrolled in cohort studies as a proxy for exposure enables the assessment of excess mortality risk across occupational sectors, addressing the lack of specific questionnaires to determine professional etiology. These findings can provide a basis for conducting targeted studies to monitor sectors of employment that may be at risk, implement effective prevention initiatives and gain a better understanding of work-related cancer etiology.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-21328-z.

Additional file 1: Table S1. Association between cause-specific mortality and sector of employment. Hazard ratios (HRs) and 95% confidence intervals (CIs) from Cox regression analysis adjusted for age, level of education, place of birth and marital status, with insurance activities used as the reference category. Rome Longitudinal Study 2011-2019. (Men and women) Fig. S1. Flow chart of the study population. Table S2. Association between cause-specific mortality and sector of employment. Hazard ratios (HRs) and 95% confidence intervals (CIs) from Cox regression analysis adjusted for age, level of education, place of birth and marital status, with administrative and support service activities used as the reference category. Rome Longitudinal Study 2011-2019. (Men). Table S3. Association between cause-specific mortality and sector of employment. Hazard ratios (HRs) and 95% confidence intervals (CIs) from Cox regression analysis adjusted for age, level of education, place of birth and marital status, with administrative and support service activities used as the reference category. Rome Longitudinal Study 2011-2019. (Women).

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Authors' contributions

Conceptualization and design: SM (Stefania Massari), LB, GC and AM; collection and assembly of data: SM (Stefania Massari), LB and GC; data analysis: LB; data interpretation: SM (Stefania Massari), LB, GC, CG and AM; manuscript writing: SM (Stefania Massari), LB, GC, CG and AM; final approval of manuscript: SM (Stefania Massari), LB, GC, CG, AM, PM, LdB, NZ, SM (Sara Maio), MS, MD and GV.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Ethics approval and consent to participate are deemed unnecessary according to the National Statistics Program (PSN 2020–2022) which grants prior authorization with the force of law of the Italian Data Protection Authority (Legislative decree No. 322 of 1989, art. 13 e art. 6-bis, comma 1-bis) for statistical works of public interest based on administrative data. Ethics approval and consent to participate are extended to all participants of the study.

Consent for publication

Not applicable for administrative data.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Occupational and Environmental Medicine, Epidemiology and Hygiene - Italian National Institute for Insurance against Accidents at Work (Inail), Via Stefano Gradi 55, Rome 00143, Italy. [2]Department of Environment and Health, Italian National Institute of Health, Rome, Italy. [3]Department of Epidemiology, Lazio Regional Health Service, ASL Roma 1, Rome, Italy. [4]Department of Statistical Sciences, Sapienza University of Rome, Rome 00185, Italy. [5]Epidemiology Unit, ASL TO3 Piedmont Region, Collegno, Torino, Italy. [6]Institute of Clinical Physiology, National Research Council (CNR), Pisa 56124, Italy. [7]Helsinki Institute for Demography and Population Health, University of Helsinki, Helsinki, Finland. [8]Max Planck, University of Helsinki Center for Social Inequalities in Population Health, Helsinki, Finland. [9]Institute of Translational Pharmacology, National Research Council (CNR), Palermo 90146, Italy.

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