Lung Cancer Mortality in the Swiss Working Population

The Effect of Occupational and Non-Occupational Factors

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Objective: To assess the effect of occupational exposures on lung cancer mortality in Switzerland after adjustment for non-occupational lung carcinogens. Methods: Using data on 4,351,383 Swiss residents, we used negative binomial regression to assess the effect occupation on lung cancer mortality between 1990 and 2014, accounting for socio-demographic factors, predicted probabilities of smoking and measured environmental radon exposure. Results: After adjustment, male machine operators and workers in mining, stone working and building materials manufacturing showed the highest risk. Women working in electrical engineering, electronics, watchmaking, vehicle construction and toolmaking, and transport occupations also remained at high risk. Radon exposure had no effect on lung cancer mortality, while smoking demonstrated a significant effect in both sexes. Conclusions: The results suggest the presence of occupational exposures to lung carcinogens in addition to non-occupational factors.

Keywords: gender differences, longitudinal study, lung cancer, occupational exposures, Switzerland, workers

Lung cancer usually has a poor prognosis and results in the highest mortality among all cancers, with 1.8 million deaths worldwide in 2020. While tobacco consumption and exposure to radon are considered as the two main risk factors, occupational exposures are also another important risk factor of lung cancer. A recent study showed that the PAF for occupational lung cancer in France, Canada, and Great Britain was estimated to be between 18% and 25% for men and between 2% and 6% for women. Accounting for 86% of all occupational cancers, lung cancer is considered the most common occupational cancer, with many IARC Group 1 human carcinogens identified in occupational settings (arsenic, asbestos, beryllium, cadmium, chromium VI, diesel exhaust, SHS, nickel, polycyclic aromatic hydrocarbons [PAHs], and silica).

In Switzerland, 12,946 men and 8314 women were diagnosed with lung cancer between 2011 and 2015, representing, respectively, 11.9% and 8.9% of the overall cancer cases. In the same period, lung cancer death accounted for 21.6% of all cancer deaths among men (n = 10,017) and 15.7% among women (n = 5872). Applying the French PAF estimated at 19.3% for males and 2.6 for females, the lung cancer burden would have diminished by 2500 and 740 cases of lung cancer in men and women over this period, respectively, in absence of occupational exposures to lung carcinogens. The Swiss National Accident Insurance Fund (Suva) recognizes less than 200 cases (mainly mesotheliomas) yearly as occupational cancers, which contrasts with expected numbers. To investigate this discrepancy, an epidemiological study based on individual occupational exposure data is necessary. Nonetheless, the occupational exposure to lung carcinogens is poorly documented in Switzerland. Conversely, environmental exposure data are available nationwide. Previous findings showed that residential exposures to radon, with relatively high levels in some Swiss regions, increased the risk of lung cancer. For smoking, data showed that 29% of Swiss adult males and 21% of females were smokers in 2015. A large discrepancy, though, has been noted between smoking consumption from surveys and actual consumption derived from aggregate data on sales. An underestimation of the true prevalence is therefore likely.

A previous study describing age-standardized lung cancer mortality rates across occupations in Switzerland found that men working in construction and in mining and quarrying, and women working in industries of trade, repair of motor vehicles and domestic articles, and in manufacture of goods had a significantly higher risk of lung cancer mortality, compared to the Swiss general population. Working in hotels and restaurants was also associated with an excess of lung cancer mortality in both sexes. Nevertheless, this first study was purely descriptive. Consequently, the present study aims at assessing the effect of occupational exposures on lung cancer mortality in Switzerland after adjustment for non-occupational lung carcinogens.

METHODS

Data Sources

The data of the Swiss National Cohort (SNC) were used to examine lung cancer in the working Swiss population. The SNC is a national longitudinal research platform for the entire resident population of Switzerland. The records of 1990 and 2000 Swiss censuses were linked to mortality, life birth, and emigration records in population of Switzerland. The records of the 1990 and 2000 Swiss censuses were linked to mortality, life birth, and emigration records in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

The authors report no conflicts of interest.

Clinical significance: This article identified occupations at high risk for lung cancer, after adjustment for non-occupational factors. Our results will allow the application of further research on at-risk groups to better understand the occupational carcinogens associated with these occupations. This will enable the design of appropriate preventive interventions. Supplemental digital contents are available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal’s Web site (www.joem.org). Address correspondence to: Nicolas Bovio, MA, Center for Primary Care and Public Health (unisamét), University of Lausanne, Lausanne, Switzerland (Mr Bovio, Dr Wild, and Pr Canu); INRS, Vandœuvre Les Nancy Cedex, France (Dr Wild).

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available within the SNC. Therefore, we used data from the 1992 Swiss Health Survey (SHS) provided by the Swiss Federal Statistical Office (SFSO) for the former, and the household radon concentration measured in 2013 by the FOPH for the latter.

Study Population
The study sample comprised adults aged 18 to 65 years included in the SNC in either the 1990 or 2000 census, with known occupation (Fig. 1). Participants with no information on socio-demographic variables (geographical regions, civil status, educational level, nationality, and municipality) were excluded.

Mortality Follow-up and Outcome Definition
The follow-up started either on December 4th 1990 (the date of the 1990 census) or on December 5th 2000 (date of the census) and lasted until the earliest of their 85th birthday, the date of emigration, death, or end of the study (December 31st 2014). Since the start and end dates of employment were unavailable, participants with a single occupation contributed to this occupation for the entire period of their follow-up, while participants who changed occupation between 1990 and 2000 census, contributed to the first occupation between 1990 and 2000, and to the second one afterward until the earliest between their 85th birthday or the end of follow-up. Causes of death from the death certificate were coded by the SFSO using the International Classification of Disease (ICD) 8th and 10th edition. Lung cancer deaths were identified using ICD8 initial cause code 162 and ICD10 primary cause code C33-C34.

Occupational Exposure
The occupation was used as a proxy of all potential occupational exposures, given the unavailability of public occupational exposure data in Switzerland. They were coded using the Swiss Standard Classification of Occupations of the SFSO, version 1990 (NSP 1990) for the 1990 census and version 2000 (NSP 2000) for the 2000 census. To harmonize the coding, we recoded NSP 1990 codes to NSP 2000 and aggregated all codes at two digits, corresponding to 39 occupational groups.

Smoking and Radon Exposure
To calculate smoking predictions, we used the data from the SHS. This is a weighted sample representative of the Swiss population including 15,278 participants, 55% of whom were women. Among them, we selected 6010 (88%) men and 6548 (78%) women who had available information on occupation (coded on NSP 2000). We then recoded the available smoking information for these participants and assigned them to either smoking or non-smoking category. Smoking probability was predicted using sex-specific logistic regressions, with smoking status as dependent variable and age, geographical region, civil status, educational level, nationality, and occupation as predictors. We then matched the predicted smoking probability to each SNC participant using as key variables the same variables as those applied in the logistic regression. The occupations with fewer than 10 observations were aggregated at the correspondent 1-digit NSP code.

Concerning radon, we used the risk of exposure based on the household radon concentration in Bq/m³ measured in 2013 by the FOPH. We assigned to each participant a risk of radon exposure (low, medium, high) based on the municipality in which they lived at the time of either of the censuses. For most municipalities, low risk was defined with an average household radon exposure lower than 100 Bq/m³, medium risk between 100 and 200 Bq/m³, and high risk with higher than 200 Bq/m³.

Statistical Analysis
For each participant, we computed person-years at risk that we stratified by calendar period (1990 to 1995, 1995 to 2000, 2000...
to 2005, 2005 to 2010, and 2010 to 2014) and age group (18 to 35, 35 to 45, 45 to 55, 55 to 65, and 65+). The lung cancer mortality rate per 100,000 person-years was assessed using negative binomial regression in order to account for overdispersion. We started with a model with age groups, calendar periods, and occupation to assess the effect of occupation on lung cancer mortality rate (model 1). We then created two other models with the addition of non-occupational factors and potential confounders. The model 2 contained the model 1 plus socio-demographic variables (geographical regions, marital status, education level, and nationality) to assess whether these variables, previously identified as being associated with smoking, had an impact on lung cancer mortality. The model 3 encompassed the model 1 adjusted for radon exposure and predicted smoking probability. All results were expressed as relative risk (RR) with respect to a reference category for each variable and the associated confidence interval at 95% (95%-CI). In all models, we used health occupations as a reference, as it has recently been identified as one of the occupational groups with the lowest risk of lung cancer. The statistical analyses were run on STATA version 16 (StataCorp LP; TX).

RESULTS

Cohort Description

In total, 4,351,383 Swiss residents were included in this study (67,922,468 person-years), 45% of whom were women (Table 1). Figure 1 illustrates their selection. The mean age at study entry was 38.1 ± 12.4 years in men and 37.2 ± 12.3 years in women, while the mean age at study end-point was 54.2 ± 12.7 years and 52.3 ± 12.7 years, respectively. A total of 208,308 participants died during the follow-up (4.8%), of whom 16,075 and 4818 were male and female lung cancer deaths, respectively. The proportions of smokers predicted on the basis of 1992 SHS data ranged between 19% and 93% in the different NSP 2 digit job categories among men, and between 1% and 89% among women. In men, the median predicted proportion was 54%, with nationality and civil status being the main independent predictors. In women, the median predicted proportion was 34%, with language region and civil status being the main independent predictors. In both sexes, occupation as coded according to NSP 2 digit was also a statistically significant predictor. Regarding exposure, the household address of about two-thirds of the participants corresponded to a low level of exposure and only 4% had a high level. Most of participants in construction, mining, technical, and computer occupations were men, while women were more than twice as likely as men to work in health, education, cultural, and scientific occupations, and three times as likely to work in hotel, restaurant, and personal service occupations.

Lung Cancer Risk Among the Swiss Working Population

Overall, the differences observed across age groups and calendar periods were statistically significant (Tables S1, http://links.lww.com/JOM/A951 and S2, http://links.lww.com/JOM/A952). While the risk decreased over time in men, we found an opposite trend in women with the highest risk in the last calendar period (2010 to 2014). In both sexes, all socio-demographic

### TABLE 1. Characteristics of the Study Sample with an Available Occupation: the Swiss National Cohort (1990–2014)

| Characteristics                                      | Male                  | Female               |
|------------------------------------------------------|-----------------------|----------------------|
|                                                      | n (\%)               | n of Lung Cancer Death (\%) |
| Total                                                | 2,403,226 (100)       | 1,948,157 (100)      |
| Person-years (in 100,000)                            | 386.04                | 293.19               |
| Nationality (binary)                                 |                       |                      |
| Swiss                                                | 1,865,423 (78)        | 1,636,679 (84)       |
| Non-Swiss                                            | 537,803 (22)          | 311,478 (16)         |
| Language region                                      |                       |                      |
| German and Rhaeto-Romansch                          | 1,756,963 (73)        | 1,416,669 (73)       |
| French                                               | 546,069 (23)          | 454,766 (23)         |
| Italian                                              | 100,194 (4)           | 76,722 (4)           |
| Civil status                                         |                       |                      |
| Single                                               | 707,098 (29)          | 599,919 (31)         |
| Married                                              | 1,532,055 (64)        | 1,103,268 (57)       |
| Widowed                                              | 18,413 (1)            | 61,036 (3)           |
| Divorced                                             | 145,660 (6)           | 183,934 (9)          |
| Highest education achieved                           |                       |                      |
| Compulsory education or less                         | 421,356 (18)          | 434,894 (22)         |
| Upper secondary level education                      | 1,304,783 (54)        | 1,227,791 (63)       |
| Tertiary level education                             | 677,087 (28)          | 285,472 (15)         |
| Vital status at study end-point                      |                       |                      |
| Alive                                                | 1,847,092 (77)        | 1,611,687 (83)       |
| Lost to follow-up                                    | 403,581 (17)          | 280,715 (14)         |
| Deceased                                             | 136,478 (6)           | 50,937 (3)           |
| Deceased from lung cancer                            | 1,948,157 (100)       | 4818 (0)             |
| Age (years): mean ± standard deviation               |                       |                      |
| At study entry                                       | 38.1 ± 12.4           | 37.2 ± 12.3          |
| At study end                                         | 54.2 ± 12.7           | 52.3 ± 12.7          |
| At death from lung cancer                            | 61.7 ± 7.9            | 59.6 ± 8.4           |
| Duration (years): mean ± standard deviation          |                       |                      |
| Follow-up                                            | 16.1 ± 6.9            | 15.1 ± 6.4           |
| Between the last occupational information and death by lung cancer | 6.9 ± 3.8 | 7.6 ± 3.8 |

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variables in model 2 yielded significant results with respect to lung cancer mortality. However, we observed that the addition of radon exposure level in model 3 had no statistically significant effect whatever the sex. In contrast, dichotomizing the predictive probability of smoking to the median demonstrated a significant effect. This effect was stronger in women than in men, with a 37% versus 33% increase in lung cancer mortality, in those with a smoking probability greater than the median versus those smoking less than the median. In the three models, the differences identified across occupations were statistically significant with a P-value lower than 0.001.

Adding socio-demographic variables in model 2, we observed that most of the RR across occupational groups decreased in both sexes compared to the reference category of health occupations (Table 2). On average, we found a 16% decrease in relative risks among occupational groups between model 1 and model 2. In
TABLE 3. Relative Risk (RR) and Confidence Interval (CI-95%) for Lung Cancer Mortality by Occupation Among Females Aged 18–85 in the Swiss National Cohort (1990–2014)

| 2-Digit NSP 2000§ | n Subjects | Observed Lung Cancer Deaths | Person-years (in 100,000) | Model 1 | Model 2 | Model 3 |
|------------------|------------|----------------------------|---------------------------|--------|--------|--------|
| 11. Occupations in agriculture, forestry, animal husbandry, and care of animals | 54,054 | 57 | 7.57 | 0.65 [0.49,0.86] | 0.66 [0.50,0.87] | 0.66 [0.50,0.87] |
| 21. Occupations in the production of food, beverages and tobacco | 11,417 | 21 | 1.61 | 1.65 [1.06,2.57] | 1.57 [1.01,2.44] | 1.63 [1.05,2.53] |
| 22. Occupations in the textile and leather industry | 38,115 | 76 | 4.82 | 1.11 [0.86,1.42] | 1.15 [0.89,1.47] | 1.10 [0.85,1.40] |
| 24. Occupations in metalworking and mechanical engineering | 12,934 | 28 | 1.69 | 1.58 [1.07,2.32] | 1.47 [1.00,2.16] | 1.51 [1.03,2.22] |
| 25. Occupations in electrical engineering, electronics, watchmaking, vehicle, and tool construction | 12,662 | 55 | 1.66 | 2.69 [2.02,3.57] | 2.33 [1.75,3.10] | 2.13 [1.59,2.85] |
| 27. Graphic arts occupations | 9902 | 27 | 1.51 | 2.24 [1.52,3.32] | 2.03 [1.37,3.00] | 2.07 [1.40,3.06] |
| 26. Occupations in the chemical and plastics industry | 18,353 | 41 | 2.82 | 1.57 [1.13,2.16] | 1.49 [1.08,2.06] | 1.28 [0.92,1.77] |
| 29. Other processing and manufacturing occupations | 22,657 | 74 | 3.03 | 1.99 [1.55,2.56] | 1.84 [1.43,2.37] | 1.80 [1.42,2.32] |
| 34. Technical staff | 5716 | 20 | 0.83 | 2.19 [1.40,3.44] | 2.05 [1.31,2.22] | 2.24 [1.42,3.51] |
| 36. Computer occupations | 13,458 | 36 | 2.04 | 2.48 [1.76,3.49] | 2.38 [1.69,3.35] | 2.18 [1.54,3.07] |
| 41. Construction occupations | 6554 | 13 | 0.88 | 1.93 [1.11,3.36] | 1.82 [1.05,3.17] | 1.64 [0.94,2.86] |
| 51. Commercial and sales occupations | 24,696 | 755 | 36.16 | 1.77 [1.56,2.01] | 1.66 [1.46,1.89] | 1.68 [1.48,1.91] |
| 52. Occupations in advertising and marketing, tourism and trust administration | 27,534 | 42 | 4.03 | 1.31 [0.95,1.80] | 1.29 [0.94,1.78] | 1.23 [0.89,1.69] |
| 53. Transport and traffic occupations | 24,748 | 83 | 3.69 | 2.43 [1.91,3.09] | 2.23 [1.75,2.83] | 2.38 [1.87,3.02] |
| 54. Postal and Telecommunications occupations | 41,879 | 99 | 6.53 | 1.47 [1.18,1.84] | 1.37 [1.09,1.71] | 1.38 [1.10,1.73] |
| 61. Occupations in the hotel and restaurant business and home economics | 181,476 | 585 | 25.25 | 2.15 [1.88,2.45] | 1.97 [1.72,2.25] | 1.96 [1.71,2.24] |
| 62. Cleaning, hygiene and personal care professionals | 123,150 | 363 | 17.34 | 1.74 [1.50,2.02] | 1.72 [1.48,2.00] | 1.70 [1.47,1.97] |
| 71. Contractors, directors and senior officials | 78,435 | 243 | 11.79 | 1.74 [1.48,2.05] | 1.71 [1.45,2.01] | 1.56 [1.32,1.84] |
| 72. Commercial and administrative occupations | 454,431 | 1288 | 71.23 | 1.76 [1.56,1.98] | 1.67 [1.48,1.88] | 1.67 [1.48,1.88] |
| 73. Banking professionals and insurance employees | 40,452 | 91 | 6.13 | 1.80 [1.43,2.26] | 1.63 [1.29,2.05] | 1.55 [1.23,1.95] |
| 74. Occupations related to law enforcement and security | 7024 | 19 | 1.02 | 1.69 [1.06,2.68] | 1.52 [0.96,2.41] | 1.47 [0.93,2.34] |
| 75. Judicial occupations | 6734 | 11 | 1.05 | 1.31 [0.72,2.38] | 1.43 [0.78,2.62] | 1.21 [0.66,2.21] |
| 81. Media occupations and related occupations | 21,536 | 48 | 3.33 | 1.16 [0.86,1.57] | 1.22 [0.90,1.65] | 1.12 [0.83,1.51] |
| 82. Artistic occupations | 25,295 | 50 | 3.86 | 1.32 [0.98,1.77] | 1.32 [0.98,1.77] | 1.24 [0.92,1.66] |
| 83. Occupations of social and spiritual assistance and education | 51,075 | 98 | 7.68 | 1.08 [0.87,1.36] | 1.08 [0.86,1.35] | 1.08 [0.86,1.35] |
| 84. Teaching and education occupations | 135,579 | 201 | 22.31 | 0.82 [0.69,0.98] | 0.86 [0.73,1.03] | 0.84 [0.70,1.00] |
| 85. Occupations in the social, human, natural, physical, and exact sciences | 9449 | 13 | 1.46 | 0.85 [0.49,1.48] | 0.97 [0.56,1.69] | 0.87 [0.50,1.51] |
| 86. Health occupations | 242,690 | 355 | 38.21 | 1.00 Ref. | 1.00 Ref. | 1.00 Ref. |

*Model 1 is adjusted for age and calendar period.
*Model 2 is adjusted for age, calendar period, and socio-demographic variables.
*Model 3 is adjusted for age, calendar period, radon annual average exposure, and smoking probability (only occupational groups with more than 10 observed lung cancer deaths are presented).
*Occupation is coded using the Swiss classification of occupations, version 2000 (NSP 2000), coded on 2 digits.
computer science, technical staff, and graphic arts were also found at high risk, with RRs more than twice that of health workers.

In model 3, the occupational groups identified with the highest risks of lung cancer mortality were the same as those observed in model 2 in both sexes. Nevertheless, the average risk reduction compared to model 1 was lower for men (4%) but higher for women (6%).

Discussion

Three models were compared to estimate the effect of occupation after accounting for socio-demographic variables and non-occupational risk factors on lung cancer mortality in Switzerland. Although the variation of RRs for occupation between models was small in most female occupational groups, in men the effect of occupation was lower when accounting for non-occupational factors. Even after adjustment for non-occupational risk factors and potential confounders, occupation as a machine operator, construction worker, and worker in hotels and restaurants was evidenced as a risk factor for lung cancer mortality, as suggested in our first descriptive study. In women working in transport and traffic occupation and electrical engineering, electronics, watching occupations, vehicle, and toolmaking was also confirmed as a risk factor of lung cancer mortality after accounting for potential confounders. All of these occupational groups are known to involve occupational exposure to Group 1 human carcinogens by IARC, adding consistency to our findings.

Contribution of Non-Occupational Factors

We observed that lung cancer risk decreased in men and increased in women over time, which appears to parallel the respective smoking trends in both sexes. Although Swiss men have historically smoked more than women, smoking prevalence among men has declined over time, while it has increased among women. Noteworthy, though, that a decrease in smoking prevalence has been observed among women born since 1970. In our study, no adjustment was made for these temporal effects, since we used SHS cross-sectional data to compute the smoking probability. Additionally, the decrease in RRs observed for all occupational groups after the addition of the socio-demographic variables in model 2 suggests that the risk for lung cancer in some occupations may be partially explained by non-occupational factors. Part of this risk can be also explained by differences in smoking behavior between categories.

Contrary to previous reports suggesting an 8% increase in lung cancer mortality per 100 Bq/m3 radon exposure, we did not observe this trend when the model was adjusted for occupational exposure and other confounding factors. Since we used aggregated data on radon exposure, we cannot rule out a potential ecological bias. However, another explanation could be that the use of residential radon exposures did not accurately reflect the true exposure to radon as most participants spent a significant portion of their time working is therefore suitable to better identify carcinogens to which they may have been exposed. Construction workers were also identified as at risk of lung cancer mortality. They were found at higher risk of lung cancer than other blue-collar workers, even after adjusting for smoking and socio-demographic variables and we also observed this. Therefore, we think it is likely that Swiss construction workers may have been exposed to IARC group 1 carcinogens such as asbestos, silica dust, and diesel engine exhaust, highly prevalent in this occupational group. Mining, stone working, and building materials manufacturing workers were also observed with a RR greater than two compared to health occupations. Consistent with SHS data showing that smoking prevalence was high in this group, we found that the risk of lung cancer mortality significantly decreased between model 1 and model 2. This is in line with prior findings where crude ORs for lung cancer among miners and quarrymen decreased from 1.59 to 2.74, to 1.18 to 2.34, when smoking-adjusted. We can assume that the remaining part of the lung cancer risk could be partially explained by exposure to occupational lung cancer carcinogens, including arsenic, asbestos, chromium (VI), nickel, PAH, silica, and diesel engine exhaust. Lastly, cleaning, hygiene and personal care, as well as transport and traffic occupations, for which there is also a high potential for exposure to lung carcinogens, would also deserve further attention.

In women, the recent Swiss descriptive study on lung cancer mortality demonstrated that motor vehicle drivers were more than twice as likely as the general population to die from lung cancer. After adjustment for non-occupational factors, we found that the RR in transport and traffic occupations remained higher than two compared with health occupations. Although previous findings have shown that these workers were exposed to diesel exhausts, they were limited to men. Moreover, authors showed that in trucking...
industry, smoking behavior did not explain variations in lung cancer risk. To our knowledge, this result is original and should be confirmed by further investigations. Moreover, the extent to which female workers in electrical engineering, electronics, watchmaking, and toolmaking were exposed to lung cancer carcinogens would also deserve more in-depth analyses. This occupational group includes different types of occupations, which makes it difficult to accurately assess the potential for occupational exposures, although exposure to welding fumes, engine exhaust, PAH, and beryllium might be present in these occupational settings.\(^{24}\) Lastly, we found no studies explaining the high RR in both computer science and graphic art in women. Assessing second-hand smoke in these occupational groups might potentially help to better understand whether the risk of lung cancer mortality is due to occupational settings or/and other risk factors.

In both sexes, workers in hotel, restaurant, and domestic economics occupations presented a significantly higher risk of lung cancer mortality than the reference group (health occupations). Almost one-quarter of hospitality workers reported being occupationally exposed to second-hand smoke between 2.1 and 4.4 hours per day.\(^ {3.7}\) Bar workers were the most exposed group with a mean exposure to second-hand smoke of 4.4 hours per day. We can thus assume that second-hand smoke would explain the excess risk of lung cancer mortality found in this study. The ban on smoking in public places was only recently signed in Switzerland and implemented between 2008 and 2010.\(^ {26}\) With a longer follow-up of this cohort and additional individual data, it should be possible to assess the effect of this measure on lung cancer mortality in these occupations.

**Limitations and Strengths**

One of the main strengths of this study lies in the availability of information at a population level with a 24-year long follow-up. Using one of the largest cohorts worldwide, we were able to define the occupational settings to approximate the occupational carcinogens before the occurrence of the outcome of interest, and thus to limit any potential information bias. The accuracy of death certificate in Switzerland was found to be satisfactory with most of malignant neoplasm,\(^{14}\) limiting outcome misclassification bias. As information was derived from national data sources, we believe that our results correctly identified occupational groups exposed to occupational lung carcinogens. Since the study sample included 45% of women, this study fulfilled the recommendation to improve the knowledge of occupational exposures and their effect on women.\(^ {46}\) Bar workers were the most exposed group with a mean exposure to second-hand smoke of 4.4 hours per day. We can thus assume that second-hand smoke would explain the excess risk of lung cancer mortality found in this study. The ban on smoking in public places was only recently signed in Switzerland and implemented between 2008 and 2010.\(^ {26}\) With a longer follow-up of this cohort and additional individual data, it should be possible to assess the effect of this measure on lung cancer mortality in these occupations.

**CONCLUSIONS**

This study reports sex-specific risk of lung cancer mortality at a national level across occupational groups, after accounting for socio-demographic variables, and radon exposure and smoking probability. Our results demonstrated that non-occupational factors, such as civil status, linguistic region, nationality, education, and smoking, were significant predictors of lung cancer. After adjusting for these factors, we observed that the risk of lung cancer mortality remained significant among some occupational groups. Men working as machine operators and in mining and construction and women working in electrical engineering, electronics, watchmaking, vehicle construction and toolmaking, computer, transport and traffic, and graphic arts presented the highest risks. In both sexes, workers in hotels and restaurants were also at risk of lung cancer mortality. Some results in women are original, as occupational exposures and their effects were rarely studied in women.

As most of the occupational groups at risk have been potentially exposed to lung cancer carcinogens, additional research should be conducted to identify occupational carcinogens related to these occupations and quantify the exposure to them. This would make it possible to target the most hazardous exposures in high-risk occupations and tailor appropriate preventive interventions. Further analyses on the histological type of lung cancer are also needed to improve both occupational risk estimates and the number of occupational lung cancers in Switzerland.

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