Original Article



# Exposure to Outdoor Air Pollution and Chronic Bronchitis in Adults: A Case-Control Study

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## Abstract

**Background:** Although Lebanon is a highly polluted country, so far no study has specifically been designed to assess the association between outdoor air pollution and chronic bronchitis in this country.

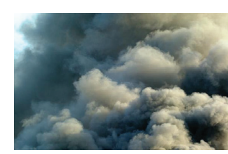
**Objective:** To assess the association between exposure to outdoor air pollution and chronic bronchitis in Lebanon.

**Methods:** A pilot case-control study was conducted in two tertiary care hospitals. Cases consisted of patients diagnosed with chronic bronchitis by a pulmonologist and those epidemiologically confirmed. Controls included individuals free of any respiratory signs or symptoms. After obtaining informed consent, a standardized questionnaire was administered.

**Results:** Bivariate, stratified (over smoking status and gender) and multivariate analyses revealed that passive smoking at home (ORa: 2.56, 95% CI: 1.73–3.80) and at work (ORa: 1.89, 95% CI: 1.13–3.17); older age (ORa: 1.75, 95% CI: 1.55–2.39); lower education (ORa: 1.44, 95% CI: 1.21–1.72); living close to a busy road (ORa: 1.95, 95% CI: 1.31–2.89) and to a local power plant (ORa: 1.62, 95% CI: 1.07–2.45); and heating home by hot air conditioning (ORa: 1.85, 95% CI: 1.00–3.43) were moderately associated with chronic bronchitis; an inverse association was found with heating home electrically (ORa: 0.58, 95% CI: 0.39–0.85). A positive dose-effect relationship was observed in those living close to a busy road and to a local diesel exhaust source.

**Conclusion:** Chronic bronchitis is associated with outdoor air pollution.

**Keywords:** Bronchitis, chronic; Air pollution, indoor; Pollution, environmental; Case-control studies



## Introduction

Chronic bronchitis is defined as abnormal production of mucus causing airflow obstruction and inflammatory changes in the bronchial mucosa leading to chronic productive cough for at least three months of the year for at least two years.[1] Chronic bronchitis is associated with physical and psychological morbidity;[2] it increases the risk of infections[3] and lung cancer[4], and may progress to chronic obstructive pulmonary disease (COPD).[2,5] The chronic presence of inflammation is also associated with poorer prognosis,[6-8] more hospitalizations[9] and

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**TAKE-HOME MESSAGE**

- Chronic bronchitis is associated with physical and psychological morbidity; it increases the risk of infections and lung cancer, and may progress to chronic obstructive pulmonary disease.
- Outdoor air pollution is a contributing factor to premature respiratory mortality and morbidity.
- Chronic bronchitis was moderately associated with passive smoking at home, older age, lower education, living close to a busy road and/or a local power plant.
- Indoor pollutions such as non-electrical heating; wood-smoke, biomass fuel are associated with COPD.
- Smoking law reinforcement, decreasing exposure to diesel exhaust by encouraging people to move away from local power generators, to dwell outside heavy traffic regions, and to heat their home electrically are required by concerned authorities.

higher economic burden associated with these disease conditions. The main cause of chronic bronchitis is smoking; however, other causes such as exposure to toxic pollutants is being suggested.[5,10-12]

For more information on early detection of lung diseases see www.theijoem.com/ijoem/index.php/ijoem/article/view/132/259

A substantial body of epidemiological research has shown that outdoor air pollution, and in particular traffic-related air pollution, is a contributing factor to premature respiratory mortality and morbidity.[13-16] In the 1960's, researchers showed that outdoor air pollution was not only the cause of sudden exacerbations in patients suffering from a chronic airways obstructive disease but also that the prevalence of chronic bronchitis appeared to be greater in areas with higher pollution.[17-22] Afterwards, Swiss investigators found that nonsmokers living within 20 m of a main street had an increased risk of regular phlegm and wheezing.[23] Many cross-sectional studies in adults comparing the prevalence of symptoms in different areas, found a higher prevalence of chronic bronchitis in areas with higher air pollution.[24-27] On the other hand, many studies were not able to reveal the effect of outdoor pollution on respiratory health.[28,29] Furthermore, several studies from different parts of the world showed that indoor pollution concentrations associated with respiratory health.[30] Currently, exposure to indoor pollutants, particularly to their solid fuel smoke, is consistently associated with chronic bronchitis; this has been shown in two recent systematic reviews and meta-analyses by Kurmi, and by Hu, *et, al.*[31,32] The effect of indoor pollutants on chronic respiratory illness in cooking women in Nepal has been reported; the rate of chronic bronchitis in women who have never smoked was of 18%.[33] Biomass fuel burning, a surrogate measure for indoor pollution, seems of particular importance. Biomass fuel refers to "any recently living plant- and/or animal-based material that is deliberately burned by humans as fuel, including wood, crop residues, and animal dung."[34] Radon and collaborators suggested that passive smoking was linked to chronic bronchitis and asthma.[35] In 2010, the American Thoracic Society stated that "traffic and other outdoor pollution, second-hand smoke, biomass smoke, and dietary factors are associated with COPD, but sufficient criteria for causation were not met."[36] Additional research is thus needed to understand the role of outdoor and indoor air pollution on adult respiratory health and to clarify the specific exposure indicators most sensitive in detecting a health effect.[37]

Lebanon is a rapidly urbanizing country, with heavy traffic in urban areas. Particulate concentrations have been found to exceed the international standards.[38,39] Moreover, in the aftermath of the war, shortage of electricity for several hours a day have lead Lebanese to buy themselves local power plants, mainly functioning on diesel. In addition, smoking in Lebanon is highly prevalent; passive smoking is also highly prevalent, since the law that bans smoking in public areas is not yet applied.[40,41] Therefore, the Lebanese population, particularly in urban regions, is heavily exposed to outdoor traffic-related particulate pollution, diesel exhaust, and tobacco smoking. However, although chronic bronchitis is highly prevalent in Lebanon (24.9%),[42] so far no study has specifically assessed the association between outdoor air pollution and chronic bronchitis. We therefore conducted this pilot study to assess the association between exposure to outdoor air pollution and chronic bronchitis in adults in Lebanon.

## Patients and Methods

### Study design

This case-control study was performed in two tertiary care hospitals in Beirut. In this study we compared a group of patients with newly diagnosed chronic bronchitis (with or without COPD) with a control group. Since the study was observational and no patient could be traced (anonymity was guaranteed), the Internal Review Board (IRB) of our institution waived the need for an official approval to perform the study, provided the study respected patients' autonomy and confidentiality. Data collection for cases and controls took place between July 2010 and September 2011 in two university hospitals of Beirut. All consecutive individuals in outpatients' clinics who fulfilled the inclusion criteria were asked to participate in the study. Only 2% of cases and 10% of controls refused to participate.

### Study population

The case (chronic bronchitis) group consisted of consecutive incident outpatient cases (newly diagnosed, not hospitalized) who were diagnosed with chronic bronchitis by a pneumonologist based on their clinical presentation (that corresponds to a chronic bronchitis diagnosis without other chronic respiratory disease) and who subsequently had positive responses to the following question: "Do you have morning productive cough for more than three months a year for more than two years?"[43] The inclusion criteria included age of 40 years or more and being free from other previously diagnosed respiratory diseases such as COPD, asthma, tuberculosis, lung cancer or fibrosis. Newly diagnosed cases of COPD were also included in the case group—$FEV_1/FVC < 70\%$ was considered "newly diagnosed COPD;" higher values considered "no COPD."[43]

For more information on inhalational lung disease see www.theijoem.com/ijoem/index.php/ijoem/article/view/4/21

The control group consisted of people free from any respiratory diseases or symptoms. It included outpatients aged 40 years of age or more who attended our center for consulting for diverse problems (*e.g.*, renal and urological, gastrointestinal, gynecological, endocrinological, cardiologic, orthopedic, rheumatologic, and ophthalmologic problems, and preoperative consultation); these patients formed 30% of controls. People accompanying patients who attended our center (family members or friends) were also asked to serve as controls; these formed 70% of controls. The exclusion criteria included having previous or current diagnosis of any respiratory diseases or suffering from any chronic respiratory symptoms.

### Sample size calculation

Sample size was calculated assuming a type I error of 5% and a study power of 80%. In the absence of baseline data, the exposure probability to pollution was considered to be equal to 50% in healthy population. The minimal sample size necessary to show a twofold increase in the risk of chronic bronchitis consisted of 333 subjects, chosen a priori to be divided into two controls (n=222) for one case (n=111). We decided to study at least two times these numbers to have an adequate power for studying the probable interactions.

## Data collection

The diagnosis of chronic bronchitis was made after a specialist confirmed the clinical diagnosis and the patient answered a questionnaire. A previously validated self-administered questionnaire, adapted to local Arabic language from the standardized and validated American Thoracic Society chronic respiratory disease Questionnaire,[44] was administered to those subjects fulfilling the inclusion criteria.

After obtaining an oral informed consent, questionnaires were given to eligible subjects by local inquirers, independently of their exposure status. The same conditions were applied for questionnaires in both cases and controls, to evaluate the diagnosis of chronic bronchitis, in addition to various risk factors including education level, occupational exposure, housing condition, smoking habits, exposure such as living close to a road with heavy traffic, and other life style factors. Other potential confounding variables including age, gender, height, weight, education, work status, and marital status were also considered.

The presence of symptoms was indicated by affirmative responses to the following questions: "Has the doctor ever told you that you have a chronic respiratory disease?" "Are you still suffering from this respiratory disease?" "Do you have any chronic respiratory symptoms?" "Do you have any chronic cough?" "Do you have any chronic expectorations?" And, "do you have morning productive cough for more than three months a year for more than two years?"

For assessing the exposure to outdoor air pollution, the following questions were asked: "Do you live in a house close to a road full of cars?" (a traffic exposure indicator). "Have you ever lived in a house close to a road full of car?" (a traffic exposure indicator). "Have you ever lived close to a local power plant?" (a diesel exhaust exposure indicator). Moreover, questions were asked about occupational toxic exposure as well as home cooking and heating methods (*e.g.*, "had you any exposure to toxic fumes during work?") Smoking habits were assessed by asking "have you ever regularly smoked (cigarette or water pipe)?" Passive smoking was evaluated by the number of smokers at home and at work, whether home smokers smoke inside and if the individual considered himself exposed to work smokers.

## Statistical analysis

Data entry was performed by independent lay persons that were unaware of the objectives of the study. Quality control of data entry and data cleaning were carried out by researchers. Statistical analysis was performed by SPSS® for Windows® ver 13.0. A p value $<0.05$ was considered statistically significant. For categorical variables, $\chi^2$ and Fisher exact tests were used when applicable. Dose-effect relationships were also evaluated by tests for trends.

Stratified analyses over "ever smoking" and over "gender" were carried out for the effect of different indoor and outdoor pollution factors over chronic bronchitis, using Cochran's and Mantel-Haenszel statistics. Homogeneity of the odds ratios (ORs) between strata was tested using Breslow-Day and Tarone's tests.

Multivariate analyses using logistic regression models were carried out to compare measures between groups of comparison, taking into account potential confounding variables that had a $p<0.20$ in bivariate analysis: ever smoking, gender, residency, age, height, weight, body mass index, education, work status, marital status and the smokers a person was potentially exposed to (passive smoking at home and work). The major dependent variable was being diagnosed with chronic bronchitis or not. Independent variables were exposures to outdoor pollution, indoor pollution, active and passive smoking, and occupational exposure to toxic gases and fumes. Two models were studied—in one, duration of living close to a road with heavy traffic and duration of living close to a local power plant were treated as dichotomous variables whereas in the other one, they were treated as continuous variables.

A stepwise descendent likelihood ratio logistic regression analysis was applied, and the final model that included significant variables ($p<0.05$) was retained. The final model was accepted after ensuring adequacy of the data using the Hosmer and Lemeshow test.

# Results

## Description of the population

A total of 833 individuals were included in the study—559 controls and 274 cases of chronic bronchitis. Out of 274 cases, 68 (24.8%) had COPD, while 206 (75.2%) did not. The mean±SD post-bronchodilator $FEV_1$/FVC of all cases was 73%±14%—for cases without COPD, it was 80%±10%, and for those with COPD it was 61%±7%.

Among cases, 121 (44.2%) were told by their physician that they suffered from a chronic respiratory disorder; 42 (15.3%) have been hospitalized at least once due to a respiratory problem. Moreover, 112 (40.9%) declared that they had periods of the year with more cough and expectorations than usual.

Of 559 controls, 355 (63.5%) declared themselves totally healthy with no chronic diseases or symptoms; the rest were classified as follows: 42 (7.5%) were consulting for cardiology problems, 15 (2.7%) for endocrinology, 19 (3.4%) for dermatology, 9 (1.6%) for hematology/oncology, 8 (1.4%) for nephrology, 9 (1.6%) for urology, 19 (3.4%) for gastroenterology, 8 (1.4%) for gynecology, 17 (3.04%) for ophthalmology, 3 (0.5%) for otorhinolaryngology problems and 15 (2.7%) for preoperative consultation. Forty (7.2%) patients did not declare the reason for their medical consultation. The mean±SD post-bronchodilator $FEV_1$/FVC for controls was 109%±24%.

## Sociodemographic characteristics of cases and controls

Baseline characteristics of cases and controls are shown in Table 1. Cases were older, included more males and more widows or divorced individuals; they were also less educated and less currently working ($p<0.01$).

## Housing conditions and chronic bronchitis

Heating home by wood burning was moderately associated with chronic bronchitis (OR: 1.60, 95% CI: 1.03–2.48), while heating home electrically was inversely associated with chronic bronchitis (OR: 0.67, 95% CI: 0.50–0.90). No significant association was found for cooking on wood, using butane gas or diesel for heating, hot air conditioning or central heating (Table 2).

**Table 1:** Baseline characteristics of cases and controls

| Characteristic | Controls n=559 (%) | Cases n=274 (%) | p value |
|---|---|---|---|
| Age (yrs) | | | |
| 40–44 | 193 (34.5) | 19 (6.9) | |
| 45–49 | 147 (26.3) | 26 (9.5) | |
| 50–54 | 71 (12.7) | 29 (10.6) | <0.001 |
| 55–59 | 48 (8.6) | 43 (15.7) | |
| 60–64 | 37 (6.6) | 42 (15.3) | |
| ≥65 | 63 (11.3) | 115 (42.0) | |
| Gender | | | |
| Males | 247 (44.1) | 148 (54.0) | 0.007 |
| Females | 312 (55.9) | 126 (46.0) | |
| Education | | | |
| Never been to school | 11 (2.0) | 10 (3.7) | |
| Primary or less | 48 (8.7) | 81 (29.4) | |
| Complementary or less | 68 (12.1) | 55 (19.9) | <0.001 |
| Secondary or less | 174 (31.1) | 82 (30.1) | |
| University degree | 258 (46.1) | 46 (16.9) | |
| Working status | | | |
| Currently working | 371 (66.4) | 98 (35.8) | |
| Retired | 50 (8.9) | 70 (25.5) | <0.001 |
| Not finding a job | 5 (0.9) | 2 (0.7) | |
| Does never work | 133 (23.8) | 104 (38.0) | |
| Marital status | | | |
| Married | 464 (83.0) | 234 (85.3) | |
| Single | 78 (13.9) | 18 (6.6) | <0.001 |
| Widow or divorced | 17 (3.1) | 22 (8.1) | |

## Active and passive smoking, occupational exposure to toxins and chronic bronchitis

Ever smoking was highly associated with chronic bronchitis (OR: 12.59, 95% CI: 7.50–21.14); a strong association was also found with passive smoking at home (OR: 3.09, 95% CI: 2.25–4.23), though no association was detected with passive smoking at work (Table 3).

## Exposure to outdoor pollution, occupational fumes and chronic bronchitis

We found that house distance less than 100 meters from a busy road (OR: 2.06, 95% CI: 1.54–2.77), ever living or currently living close to a busy road (OR: 1.61, 95% CI: 1.20–2.15), duration of living close to a busy road (p=0.001, test for trend), ever living close to a local power plant (OR: 2.10, 95% CI: 1.54–2.86), du-

**Table 2:** Association between housing conditions (indoor pollution) and chronic bronchitis

| Variable | Controls n=559 (%) | Cases n=274 (%) | OR (95% CI) |
|---|---|---|---|
| Heating home by gas | | | |
| No | 310 (55.5) | 153 (55.8) | 0.985 (0.74–1.32) |
| Yes | 249 (44.5) | 121 (44.2) | |
| Heating home by wood | | | |
| No | 505 (90.3) | 234 (85.4) | 1.60 (1.03–2.48) |
| Yes | 54 (9.7) | 40 (14.6) | |
| Heating home by diesel | | | |
| No | 469 (83.9) | 226 (82.5) | 1.10 (0.75–1.63) |
| Yes | 90 (16.1) | 48 (17.5) | |
| Heating home electrically | | | |
| No | 261 (46.7) | 155 (56.6) | 0.67 (0.50–0.90) |
| Yes | 298 (53.3) | 119 (43.4) | |
| Heating home by hot air | | | |
| No | 512 (91.6) | 242 (88.3) | 1.44 (0.90–2.32) |
| Yes | 47 (8.4) | 32 (11.7) | |
| Heating home centrally | | | |
| No | 410 (73.3) | 216 (78.8) | 0.74 (0.52–1.04) |
| Yes | 149 (26.7) | 58 (21.2) | |
| Cooking on wood | | | |
| No | 550 (98.4) | 265 (96.7) | 2.08 (0.81–5.29) |
| Yes | 9 (1.6) | 9 (3.3) | |

ration of living near a local power plant ($p<0.001$, test for trend), and ever being occupationally exposed to toxic fumes (OR: 2.09, 95% CI: 1.43–3.08) were moderately associated with chronic bronchitis (Table 4).

## Stratified analysis

This analysis was carried out for exposure to diesel exhaust and living close to a road with heavy traffic, to test if these variables are associated with chronic bronchitis in strata of smokers and never smokers. No interaction was observed neither between smoking and other studied exposures, nor between gender and other exposures in never smokers.

Ever living close to a power generator was not a risk for never smokers (OR: 1.23, 95% CI: 0.44–3.48); in smokers, it was 2.88 (95% CI: 1.97–4.20). Mantel-Haenszel statistics gave a significant $OR_{MH}$ of 2.61 (95% CI: 1.84–3.70).

Living close to a road with heavy traffic was also not a risk for never smokers (OR: 2.64, 95% CI: 0.90–7.71); it was for smokers (OR: 1.83, 95% CI: 1.31–2.57). Mantel-Haenszel statistics gave a significant $OR_{MH}$ of 1.90 (95% CI: 1.38–2.62).

When stratifying over gender, similar results were found. Living close to a power plant was a risk for both men (OR: 1.95, 95% CI: 1.27–3.01), and women (OR: 2.19, 95% CI: 1.41–3.42). Mantel-Haenszel statistics gave a significant $OR_{MH}$ of 2.06 (95% CI: 1.51–2.82).

Living close to a road with heavy traffic, was not a risk for men (OR: 1.30, 95%

**Table 3:** Subject's exposure to active, passive smoking, occupational toxins and chronic bronchitis

| Variable | Controls n=559 (%) | Cases n=274 (%) | OR (95% CI) |
|---|---|---|---|
| Ever smoking | | | |
| No | 254 (45.4) | 17 (6.2) | 12.59 (7.50–21.14) |
| Yes | 305 (54.6) | 257 (93.8) | |
| Home smokers | | | |
| No Smoker | 298 (53.3) | 74 (27.0) | 3.09 (2.25–4.23) |
| More than one | 261 (46.7) | 200 (73.0) | |
| Do they smoke inside the house? | | | |
| No | 329 (58.9) | 90 (32.8) | 2.92 (2.16–3.96) |
| Yes | 230 (41.1) | 184 (67.2) | |
| Exposed to cigarette smoke at work? | | | |
| No | 472 (84.4) | 226 (82.5) | 1.15 (0.78–1.70) |
| Yes | 87 (15.6) | 48 (17.5) | |

CI: 0.86–1.95), but it was not in women (OR: 1.91, 95% CI: 1.26–2.90). Mantel-Haenszel statistics gave a significant $OR_{MH}$ of 1.57 (95% CI: 1.17–2.10).

### Multivariate analysis

Including all factors in a multivariate stepwise descendent logistic regression model, revealed that passive smoking at home and work, ever smoking, older age, lower education, living close to a busy road and/or a local power plant, and heating home by hot air conditioning were independent risk factors for chronic bronchitis. Moreover, an inverse association was found between chronic bronchitis with heating home electrically (Table 5). The model was suitable and adequate to data (Nagelkerke $R^2$=0.457; Hosmer and Lemeshow test p=0.181). Non-retained variables in the model included gender, heating home by gas, occupational exposure to fumes, cooking on wood, heating home on wood, diesel, or centrally (Table 5).

We also conducted another analysis where we treated the duration of living close to a road with heavy traffic and duration of living close to a local power plant as independent variables instead of dichotomous variables; the rest of the variables were treated as in the previous model. Results were essentially the same: the ORa was 1.01 (95% CI: 1.00–1.02, p=0.017) for duration of living close to a road with heavy traffic; the ORa was 1.46 (95% CI: 1.09–1.95, p=0.012) for duration of living near a local power plant. Nonretained variables in the model included gender, heating home by gas, occupational exposure to fumes, cooking on wood, heating home on wood, diesel, and centrally.

## Discussion

In this study, we found that chronic bronchitis was moderately associated with passive smoking at home, older age, lower education, living close to a busy road and/or a local power plant, and heating home by hot air conditioning were moderately associated with chronic bronchitis; the disease had an inverse association with heating home electrically. These results were confirmed by stratified and mul-

**Table 4:** Exposure to outdoor pollution, occupational fumes and chronic bronchitis

| Variable | Control n=559 (%) | Cases n=274 (%) | OR (95% CI) |
|---|---|---|---|
| Actual house close to road full of cars | | | |
| > 100 m | 360 (64.4) | 128 (46.7) | 2.06 (1.54–2.77) |
| < 100 m | 199 (35.6) | 146 (53.3) | |
| Ever lived close to a road full of cars | | | |
| No | 321 (57.4) | 125 (45.6) | 1.61 (1.20–2.15) |
| Yes | 238 (42.6) | 149 (54.4) | |
| Living duration close to a busy road* | | | |
| Never | 321 (57.4) | 125 (45.6) | 1.00 |
| 1 to 14 years | 50 (8.9) | 26 (9.5) | 1.34 (0.98–2.24) |
| 15 to 30 years | 86 (15.4) | 38 (13.9) | 1.14 (0.74–1.75) |
| 31 years or more | 102 (18.2) | 85 (31.0) | 2.14 (1.50–3.05) |
| Ever lived close to a local power plant | | | |
| No | 422 (75.5) | 163 (59.5) | 2.10 (1.54–2.86) |
| Yes | 137 (24.5) | 111 (40.5) | |
| Living duration near a power plant* | | | |
| Never | 448 (80.1) | 177 (64.4) | 1.00 |
| 1 to 10 years | 52 (9.3) | 45 (16.6) | 2.12 (1.42–3.48) |
| 11 years or more | 59 (10.6) | 52 (19.0) | 2.22 (1.45–3.40) |
| Exposure to toxic fume during work | | | |
| No | 493 (88.2) | 214 (78.1) | 2.09 (1.43–3.08) |
| Yes | 66 (11.8) | 60 (21.9) | |

tivariate analysis. Moreover, a positive dose-effect relationship was found for variables living close to a busy road and/or a local diesel exhaust source.

Our findings were similar to those of other researchers for several factors: Besides smoking, male gender, advanced age and lower education have also been reported to increase the risk of chronic bronchitis.[45] Passive smoking is a known cause of chronic bronchitis.[46,47] Many researchers reported chronic bronchitis due to outdoor traffic pollution.[24-27] High traffic intensity, however, may not only correlate with high total number of vehicles, but also with a higher proportion of heavy vehicles—an additional factor which could affect the outcome—since diesel exhaust from heavy vehicles might have more adverse respiratory effects.[48-50] The latter factor is also related to the local power plant proximity association with chronic bronchitis we found in our study.

For indoor pollution, the inverse relationship with electrical heating reflects the fact that all non-electrical means for heating may increase the risk of chronic bronchitis; in other words, this variable could be considered an inverse surrogate measure of solid biomass and non-solid fuel use. This finding was similar to those reported for wood-smoke association with chronic bronchitis,[51] biomass exposure and respiratory diseases,[52] biomass fuel and COPD,[53] and additional reviews.[31,32] In terms of public health practice, these

**Table 5 :** Logistic regression of chronic bronchitis

| Variable | ORa (95% CI) |
|---|---|
| Global model* | |
| Passive smoking at work *vs* no | 1.89 (1.13–3.17) |
| Passive smoking at home *vs* no | 2.56 (1.73–3.80) |
| Ever smoking *vs* no | 1.93 (1.56–2.39) |
| Higher age class *vs* lower age class | 1.75 (1.55–2.39) |
| Lower education *vs* higher education | 1.44 (1.21–1.72) |
| Living close to a busy road *vs* no | 1.95 (1.31–2.89) |
| Ever living close to a local power plant *vs* no | 1.62 (1.07–2.45) |
| Heating home by hot air *vs* no | 1.85 (1.00–3.43) |
| Heating home electrically *vs* no | 0.58 (0.39–0.85) |
| Dose-effect relationship** | |
| Lower education *vs* higher | 1.35 (1.12–1.64) |
| Heating home electrically *vs* no | 0.72 (0.49–1.07) |
| Heating home by hot air | 1.89 (0.97–3.70) |
| Higher age class *vs* lower age class | 1.67 (1.48–1.89) |
| Ever smoking *vs* no | 11.26 (6.05–20.94) |
| Passive smoking at home | 2.17 (1.42–3.32) |
| Duration of living close to a road with heavy traffic | 1.01 (1.00–1.02) |
| Duration of living close to a local power plant | 1.46 (1.09–1.95) |

*n=824; 272 cases and 552 controls; Nagelkerke $R^2$=0.457; Hosmer and Lemeshow test p=0.181 – Unretained variables in the model included gender, heating home by gas, occupational exposure to fumes, cooking on wood, heating home on wood, diesel, or centrally.
**n=767; 251 cases and 516 controls; Nagelkerke $R^2$=0.484; Hosmer and Lemeshow test p=0.962 – Unretained variables in the model included gender, heating home by gas, occupational exposure to fumes, cooking on wood, heating home on wood, diesel, or centrally.

results suggest that prevention of chronic respiratory diseases is necessary in Lebanon: smoking law reinforcement, decreasing exposure to diesel exhaust by encouraging people to move away from local power generators, to dwell outside heavy traffic regions, and to heat their home electrically are required by concerned authorities.

However, although women and non-smokers have been demonstrated to be more sensitive to these types of exposure,[54,55] we were not able to identify any differential effect of outdoor or indoor pollution on women compared to men and in non-smokers compared to smokers. The low study sample size may explain the absence of significant heterogeneity in ORs in different tested strata. This may also be due to the use of generic tools that are not gender sensitive for both exposure and disease evaluation.[56] Additional studies are thus necessary to depict the differential effects of pollution on respiratory diseases by gender and smoking status.

Moreover, although occupational exposure to toxic agents is associated with chronic respiratory diseases,[57] we could only observe this association in bivariate analysis, but not in multivariate analysis:

this could be explained by the fact that exposure was evaluated according to subject declaration without any further objective evaluations, or by the low study sample size—in both situations, we would witness a decrease in the study power to detect significant associations. Further studies could help to clarify this issue too.

We are aware of possible weak points in our study: a selection bias is possible, since we have no means to evaluate the reasons for not responding. Still, we think that non-responders were probably not motivated, and we have no reasons to believe that this would affect the results of our study in a differential manner. On the other hand, a classification bias is possible regarding self-reporting answers on all questions; nevertheless, as in all studies relying on questionnaires, this would direct the results toward the null and underestimate the associations we found. Moreover, because of the retrospective assessment of exposure, misclassification may be possible. Finally, although we carried out a multivariate analysis to remove the confounding effects of several factors, there is still a possibility of residual confounding due to unmeasured factors, such as domestic exposure to chemicals (pesticides, painting dies, *etc*.). However, the biological plausibility, external validity, dose-effect and temporal relationships and robust results of the multivariate analysis may all direct us toward an increased likelihood of the causality of the association with chronic bronchitis. Increasing the likelihood of this causality would only be possible with future prospective studies that take into account these weak points, and by experimental studies. We also suggest future studies that define pollution exposure more precisely.

In conclusion, we found that outdoor pollution exposure, such as living close to a busy road and/or a local power plant, were associated to chronic bronchitis; in addition, indoor pollution factors such as exposure to passive smoking and heating home other than electrically were also associated with this disease. These results were also demonstrated by dose-effect relationships, stratified and multivariate analyses. Additional studies are necessary to show the causality of these associations.

**Conflicts of Interest:** None declared.

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