# Neighborhood linking social capital as a predictor of lung cancer: A Swedish national cohort study

Tsuyoshi Hamano[a,b,*], Xinjun Li[c], Jan Sundquist[b,c,d], Kristina Sundquist[b,c,d]

[a] Department of Sports Sociology and Health Sciences, Faculty of Sociology, Kyoto Sangyo University, Motoyama, Kamigamo, Kita-ku, Kyoto, 603-8555, Japan
[b] Center for Community-Based Health Research and Education, Organization for the Promotion of Project Research, Shimane University, 89-1 Enya-cho, Izumo, Shimane, 693-8501, Japan
[c] Center for Primary Health Care Research, Lund University, Clinical Research Centre (CRC), Building 28, Floor 11, Jan Waldenströms gata 35, Skåne University Hospital, SE-205 02, Malmö, Sweden
[d] Department of Family Medicine and Department of Community Health and of Population Health Science and Policy, Icahn School of Medicine at Mount Sinai, One Gustave L. Levy Place, Box 1077, New York, NY, 10029, USA

## ABSTRACT

*Background:* The aim of this nationwide follow-up study was to examine whether neighborhood linking social capital is associated with lung cancer, including incident and mortality cases, after adjustment for individual- and familial-level factors.

*Methods:* This follow-up study comprised 2,123,707 men and 2,046,174 women aged 25 years or older in Sweden. The follow-up period started on January 1, 2002 and proceeded until first incident of lung cancer, mortality of lung cancer, death from any other cause, emigration or the end of the study period on December 31, 2010. Multilevel logistic regression models (individual-level factors at the first level and neighborhood-level factors at the second level) were used to calculate odds ratios (ORs) with 95% confidence intervals (95% CIs).

*Results:* We identified 16,561 lung cancer cases (8422 men and 8139 women) during the follow-up period. Higher ORs of lung cancer, including incident and mortality cases, were observed in individuals who lived in neighborhoods with low social capital (men: OR = 1.37, 95% CI = 1.27–1.47; women: OR = 1.32, 95% CI = 1.23–1.42) than in those living in neighborhoods with high social capital, after adjustment for potential confounding factors.

*Conclusion:* The results of this large national cohort study suggest that neighborhood linking social capital has important independent effects on lung cancer, including incident and mortality cases. These findings indicate that decision-makers must consider the effect of neighborhood-level factors as well as individual- and familial-level factors.

## 1. Introduction

Lung cancer is the leading cause of cancer-related death worldwide, and in 2012, 1.82 and 1.59 million new lung cancer cases and lung-cancer-related deaths were observed, respectively [1]. The incidence and mortality rates of lung cancer vary by region [2]. For example, in men, the highest incidence rates were noted in Central and Eastern Europe, whereas the lowest incidence rates were observed in Middle and Western Africa [2]. In women, the highest incidence rates were noted in Northern America, whereas the lowest incidence rates were observed in Middle and Western Africa [2]. Numerous studies have revealed the risk factors related to lung cancer, including demographic characteristics (e.g., age, sex, and race) [2–4], lifestyle habits (e.g., smoking and physical inactivity) [5,6], health conditions (e.g., chronic bronchitis, emphysema, pneumonia, and tuberculosis) [7], air pollutants (e.g., diesel exhaust emission and particular matter) [2] and inherited susceptibility [8].

During the past decades, the number of studies focusing on the influences of the social environment on health has been increasing [9]. One important aspect of the social environment is social capital, which has been frequently operationalized as a collective dimension of society that is external from an individual [9], and it is established through social relationships that can improve the efficiency of the society by facilitating coordinated actions [10]. Szreter and Woolcock described

three concepts of social capital: bonding, bridging, and linking social capital [11]. Bonding social capital refers to trusting and cooperative relations between members of a network who are similar in terms of social identity (e.g., race/ethnicity), whereas bridging social capital refers to connections between individuals who are dissimilar with respect to social identity [11–13]. Linking social capital refers to connections between individuals/groups who interact across explicit power or authority gradients in society [11–13]. Although there is considerable evidence of an association between bonding and bridging social capital and various indicators of health [13–18], few studies have examined associations between linking social capital and certain health outcomes, e.g., coronary heart disease [19], poor mental health [20], poor self-rated health [21], and mortality [22].

To the best of our knowledge, no large-scale cohort study that has focused on the association between neighborhood linking social capital and lung cancer using a multilevel framework has been conducted. Previous studies have suggested the potential mechanisms of the association between social capital and individual health: diffusion of knowledge on health promotion, maintenance of healthy behavioral norms (including smoking habits) through informal social control, and psychological processes that provide affective support [9,13,14]. These findings from previous studies led to our hypothesis that low linking social capital may be associated with an increased risk of lung cancer incidence and mortality. In addition, we examined whether the hypothesized association between linking social capital and lung cancer remains significant after adjustment for potential confounding factors.

## 2. Methods

### 2.1. Data sources

Data used in this study were retrieved from several national registers that contain information on the entire population of Sweden. The dataset we used contains nationwide information on parents and their offspring at the individual and neighborhood level, including comprehensive demographic and socio-economic data. The registers used in the present study were the Total Population Register, the Multi-Generation Register (1932–2010), the Hospital Discharge Register (1964–2010), the Cancer Register (1958–2010), the Outpatient Register (2001–2010), and the National Registry of Causes of Death (1961–2010), the latter to identify date and cause of death. The Swedish nationwide population and health care registers have exceptionally high completeness and validity. Individuals (born between 1932–1977) were tracked using the personal identification numbers, which are assigned to each resident of Sweden. These identification numbers were replaced with serial numbers to provide anonymity.

To examine the effect of the exposure (linking social capital at the neighborhood-level), all individuals were geocoded to their neighborhoods of residence. Small area market statistics (SAMS) were used to define neighborhoods, which are small administrative areas in Sweden with an average population of about 1000 residents. The SAMS boundaries were drawn to include similar types of housing construction in a neighborhood, which implies that SAMS neighborhoods are comparatively homogeneous in terms of socioeconomic structure. A total of 8398 SAMS units were included in the present study. The study period started on January 1, 2002 and proceeded until first incident of lung cancer, mortality of lung cancer, death from any other cause, emigration or the end of the study period on December 31, 2010. During the follow-up period, there were 117,193 (2.8%) individuals who died from any other cause, and 52,374 (1.3%) who emigrated from Sweden. Individuals who had unknown neighborhood information (n = 44,915, 1.1%) were excluded.

This study was approved by the ethics committee of Lund University.

### 2.2. Predictor variable

We chose to define linking social capital as voting in local government elections. According to Lochner et al., civic participation and engagement is one important aspect of social capital [23] and high voting rates are related to high levels of civic engagement. Researchers on civic engagement have divided civic engagement into three categories: civic, electoral, and political voice [24], where the second category, i.e., electoral, refers to voting. The reason for choosing voting in local government elections instead of national voting was that this choice enabled us to include immigrants without Swedish citizenship in the construction of the neighborhood-level variable. Refugees and immigrants born abroad may vote in local government elections after a minimum of one year's residence in Sweden. However, voting in national elections requires Swedish citizenship and the age of 18 years and older. Participation in voting in local government election is therefore likely to be a good indicator of linking social capital.

Previous studies conducted in Sweden used voting rates in local government elections as a proxy of linking social capital [19–22], because of the devolved nature of the government in Sweden as well as its stable voting pattern. Voting is not compulsory by law in Sweden. The number of people voting in national and local government elections has not been affected by get-out-the-vote campaigns or other actions of interest groups or political parties. As a result, voting during local government elections is believed to be a relatively stable variable over time and thus the participation rates in local government elections can be considered a good indicator of neighborhood linking social capital.

Neighborhood linking social capital was conceptualized as the number of people in the neighborhood (SAMS) who voted in local government elections divided by the number of people in the neighborhood who were entitled to vote at baseline (2002). Neighborhoods were divided into the following three linking social capital groups based on the proportions of residents who voted: (1) low, (2) intermediate, and (3) high. Group 1 comprised the 20% of neighborhoods with the lowest proportions of voters ($\leq 74.0\%$). Group 2 comprised the 60% of neighborhoods with intermediate proportions of voters (74.1–82.0%), and group 3 comprised the 20% of neighborhoods with the highest proportions of voters ($> 82.0\%$).

### 2.3. Outcome variables

The outcome variable was incident (yes/no) and mortality (yes/no) cases from lung cancer combined into a single variable for the main analyses. The unit of observation was the individual. We used the Swedish Cancer Registry to identify the primary diagnoses of lung cancer in the study population during the study period. This information was then linked to the records in the Cause of Death Register to identify deaths among patients with lung cancer during the same period. All cancer cases in Sweden must be registered in the Swedish Cancer Registry. The completeness of cancer registration is currently close to 100%. Only primary neoplasms of the lung classified according to the 7th revision of the International Classification of Diseases (ICD-7) were studied. The Swedish Cancer Registry has transferred all the cancer ICD codes into ICD-7 codes; in this study code 162, 163 were used. The outcome variable of mortality due to lung cancer in the Cause of Death Register was defined according to ICD-10 (codes C33 and C34).

### 2.4. Independent variables

The independent variables were sex, age at the start of the study, marital status, family income, educational attainment, immigration status, geographical region, mobility, diagnosis of chronic obstructive pulmonary disease (COPD), tobacco abuse, alcoholism or alcohol-related liver disease, and a family history of lung cancer.

*Sex*: Both men and women were included.

*Age*: The participants were 25–78 years at baseline.

*Marital status*: Classified as married/cohabiting or single (including divorced and widows/widowers).

*Family income*: Information on family income in 2002 came from the Total Population Register, which was provided by Statistics Sweden. We used this information to determine the distribution of family incomes in Sweden, and then used the distribution to calculate empirical quartiles.

*Educational attainment*: Classified as the completion of compulsory school or less (≤ 9 years), practical high school or some theoretical high school (10–12 years), or theoretical high school and/or college (> 12 years).

*Immigration status*: Individuals who were born in (1) Sweden and (2) outside of Sweden.

*Region of residence*: Classified as living in a large city, Southern Sweden, and Northern Sweden.

*Mobility*: Classified as the length of time lived in the neighborhood, i.e., < 5 or ≥ 5 years.

*Comorbidities:* Individuals who had a previous diagnosis of COPD, which was suspected as an important prognostic factor for lung cancer and used as a surrogate for smoking, were identified in the Hospital Registry 15 years before the start of the follow-up period and in the Out-patient Register as well as during the entire follow-up period, accordingly (ICD-9, 1987–1996: 490–496; ICD-10, 1997–2010: J40–J49). The same approach was used to identify individuals with a history of tobacco abuse or a disorder/registration that is commonly related to tobacco abuse, the latter marked in italics among the following list of ICD codes: ICD-10, F17 (Mental and behavioral disorders due to use of tobacco), T65.2 (Toxic effect of tobacco and nicotine), Z71.6 (Tobacco abuse counselling), and Z72.0 (Tobacco use); ICD-9, 305.1 (Tobacco use disorder), *292.0 (Drug withdrawal)*, 292.1 *(Drug-induced psychotic disorders)*, 292.2 *(Pathological drug intoxication)*, 292.8 *(Other specified drug-induced mental disorders)*, 292.9 *(Unspecified drug-induced mental disorder)*, V15.8 *(Other specified personal history presenting hazards to health)*, V65.3 *(Dietary surveillance and counseling)*, and V65.8 *(Other reasons for seeking consultation)*. In the patient registries, COPD and tobacco abuse were individually linked to the patient's lung cancer status. Individuals with a history of alcoholism or alcohol-related liver disease were identified from the Hospital Registry and Out-patient Register according to the ICD codes (ICD-9, 291, 303, and 571; ICD-10, F10 and K70).

*Family history of lung cancer*: A family history (parents or siblings) of hospitalization because of lung cancer (1958–2010) or death (1961–2010) due to lung cancer was defined as yes or no.

### 2.5. Statistical analyses

We used multilevel (hierarchical**)** logistic regression models because it is a good approximation of multilevel Cox proportional hazards models under conditions such as ours: a large sample size, low incidence rates, risk ratios of moderate size and a relatively short follow-up [25]. Multilevel (hierarchical**)** logistic regression models estimate odds ratios (ORs) and 95% confidence intervals (95% CIs). We performed the multilevel analyses at two levels with the individual-and family-level variables (i.e., sex, age at the start of the study, marital status, family income, educational attainment, immigration status, geographical region, mobility, comorbidities, and family history of lung cancer) at the first level and the neighborhood-level variable, i.e., linking social capital, at the second level.

The analyses were performed using MLwiN version 2.35 (University of Bristol, Bristol, the UK). Random intercept multilevel logistic regression models were used to allow for the clustering of individuals within neighborhoods and to estimate the variance in the risk for lung cancer that is attributable to neighborhood characteristics. This approach was used to estimate the intraclass correlation coefficient (ICC), showing the proportion of variance in the outcome attributable to the differences between individuals in different neighborhoods in contrast to the differences between individuals within the same neighborhood [26]. The ICC was estimated by utilizing the latent variable method as exemplified by

$$ICC = V_n/(V_n + \pi^2/3),$$

where $V_n$ is the variance between neighborhoods and $\pi^2/3$ is the variance between individuals.

The proportion of the second-level variance explained by different variables was calculated as

$$V_{EXPLAINED} = (V_0 - V_1)/V_0 \times 100,$$

where $V_0$ is the second-level variance in the initial model and $V_1$ is the second-level variance in the different models.

Parameters were estimated using marginal quasi-likelihood (MQL) methods.

### 2.6. Sensitivity analysis

Data used in a sensitivity analysis was obtained from the Swedish Medical Birth Register (women) and the Military Conscription Register (men). The Medical Birth Register includes data on smoking habits based on medical records from maternity clinics and the Military Conscription Register includes data on smoking habits from a structured and standardized medical assessment of Swedish men. Smoking habits were assessed by the number of cigarettes per day. The study period started on January 1, 2002 and proceeded until first incident of lung cancer, mortality of lung cancer, death from any other cause, emigration or the end of the study period on December 31, 2010. The initial population for the women and men was 57,953 and 43,997, respectively.

## 3. Results

Table 1 shows the population distribution and number of lung cancer incident and mortality cases. Of the total population, 21%, 58%, and 21% lived in neighborhoods characterized by low, intermediate, and high linking social capital, respectively. A total of 16,561 lung cancer cases were identified during the follow-up period.

Table 2 shows the ORs with 95% CIs for the association between linking social capital and lung cancer, including incident and mortality cases, in men. A gradient was observed between linking social capital and lung cancer, as individuals living in neighborhoods with low linking social capital were more likely to have lung cancer compared with those living in neighborhoods with high linking social capital (Model 1: OR = 1.47; 95% CI = 1.37–1.57). Individuals living in neighborhoods with intermediate linking social capital were also more likely to have lung cancer (Model 1: OR = 1.17; 95% CI = 1.10–1.25). After adjustment for potential confounders, the OR of individuals with lung cancer who were living in neighborhoods with low linking social capital decreased to 1.37 (95% CI = 1.27–1.47) but remained significant (Model 4). The OR of individuals living in neighborhoods with intermediate linking social capital also remained significant (Model 4: OR = 1.17; 95% CI = 1.09–1.24). Significant associations were observed between the individual- and familial-level variables and the ORs of individuals with lung cancer.

Table 3 shows the association between linking social capital and lung cancer, including incident and mortality cases, in women. Similar patterns were observed as in men, as women living in neighborhoods with low linking social capital were more likely to have lung cancer compared with those living in neighborhoods with high linking social capital (Model 1: OR = 1.61; 95% CI = 1.50–1.73). Individuals living in neighborhoods with intermediate linking social capital were also more likely to have lung cancer (Model 1: OR = 1.17; 95% CI = 1.10–1.24). After adjusting for potential confounders, the OR of

**Table 1**

Distribution of population, number of lung cancer incident and mortality cases, and age-standardized rate (per 1000 population) by linking social capital.

| | Population | | Lung cancer cases | | Rates by linking social capital | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | No. | (%) | No. | (%) | Low | Intermediate | High |
| **Total population (%)** | 4,169,881 | | | | 894,829 (21%) | 2,409,167 (58%) | 865,885 (21%) |
| **Total lung cancer cases** | | | 16,561 | | 5.0 | 3.8 | 3.3 |
| **Sex** | | | | | | | |
| Male | 2,123,707 | 50.9 | 8,422 | 50.9 | 5.1 | 3.9 | 3.2 |
| Female | 2,046,174 | 49.1 | 8,139 | 49.1 | 5.0 | 3.7 | 3.3 |
| **Age (years)** | | | | | | | |
| 25–34 | 999,740 | 24.0 | 233 | 1.4 | 0.4 | 0.2 | 0.2 |
| 35–44 | 1,026,126 | 24.6 | 819 | 4.9 | 1.2 | 0.8 | 0.5 |
| 45–54 | 979,636 | 23.5 | 3,284 | 19.8 | 4.6 | 3.3 | 2.5 |
| 55–64 | 885,980 | 21.2 | 8,273 | 50.0 | 12.4 | 9.1 | 7.3 |
| ≥65 | 278,399 | 6.7 | 3,952 | 23.9 | 18.1 | 13.5 | 12.1 |
| **Family income** | | | | | | | |
| Low income | 1,045,717 | 25.1 | 3,364 | 20.3 | 5.7 | 4.4 | 3.6 |
| Middle-low income | 1,040,085 | 24.9 | 4,600 | 27.8 | 5.8 | 4.3 | 3.9 |
| Middle-high income | 1,042,332 | 25.0 | 4,691 | 28.3 | 4.8 | 3.9 | 3.5 |
| High income | 1,041,747 | 25.0 | 3,906 | 23.6 | 3.8 | 3.2 | 2.8 |
| **Marital status** | | | | | | | |
| Married/cohabiting | 2,015,007 | 48.3 | 8,517 | 51.4 | 4.0 | 3.2 | 3.0 |
| Never married, widowed, or divorced | 2,154,874 | 51.7 | 8,044 | 48.6 | 6.0 | 4.8 | 4.0 |
| **Educational attainment** | | | | | | | |
| ≤9 years | 835,458 | 20.0 | 6,919 | 41.8 | 6.6 | 5.1 | 4.5 |
| 10–12 years | 1,365,442 | 32.7 | 5,487 | 33.1 | 5.2 | 4.0 | 3.8 |
| > 12 years | 1,968,981 | 47.2 | 4,155 | 25.1 | 3.2 | 2.7 | 2.4 |
| **Immigrant status** | | | | | | | |
| Sweden | 4,065,672 | 97.5 | 16,388 | 99.0 | 5.1 | 3.9 | 3.3 |
| Other countries | 104,209 | 2.5 | 173 | 1.0 | 3.2 | 2.2 | 1.9 |
| **Region of residence** | | | | | | | |
| Large cities | 2,021,860 | 48.5 | 8,525 | 51.5 | 5.9 | 4.4 | 3.4 |
| Southern Sweden | 1,435,769 | 34.4 | 5,644 | 34.1 | 4.7 | 3.7 | 3.3 |
| Northern Sweden | 712,252 | 17.1 | 2,392 | 14.4 | 3.5 | 3.0 | 2.6 |
| **Mobility** | | | | | | | |
| Not moved | 2,982,094 | 71.5 | 13,597 | 82.1 | 4.8 | 3.7 | 3.2 |
| Moved | 1,187,787 | 28.5 | 2,964 | 17.9 | 5.9 | 4.3 | 3.8 |
| **Hospitalization of chronic lower respiratory disease** | | | | | | | |
| No | 4,033,313 | 96.7 | 13,457 | 81.3 | 4.2 | 3.3 | 2.8 |
| Yes | 136,568 | 3.3 | 3,104 | 18.7 | 18.1 | 15.5 | 14.5 |
| **Hospitalization of alcoholism and related liver disease** | | | | | | | |
| No | 4,055,023 | 97.2 | 15,243 | 92.0 | 4.7 | 3.7 | 3.2 |
| Yes | 114,858 | 2.8 | 1,318 | 8.0 | 11.4 | 9.7 | 8.4 |
| **Tobacco abuse** | | | | | | | |
| No | 4,151,093 | 99.5 | 16,034 | 96.8 | 4.9 | 3.7 | 3.2 |
| Yes | 18,788 | 0.5 | 527 | 3.2 | 23.4 | 23.0 | 26.1 |
| **Family history of lung cancer** | | | | | | | |
| No | 3,946,261 | 94.6 | 14,425 | 87.1 | 4.7 | 3.6 | 3.0 |
| Yes | 223,620 | 5.4 | 2,136 | 12.9 | 9.6 | 7.5 | 6.9 |

individuals with lung cancer in neighborhoods with low linking social capital decreased to 1.32 (95% CI = 1.23–1.42) but remained significant (Model 4). The ORs of individuals living in neighborhoods with intermediate linking social capital also remained significant (Model 4: OR = 1.10; 95% CI = 1.03–1.17). There were several significant associations between the individual- and familial-level variables and the ORs of being lung cancer.

We explored lung cancer incident cases and mortality cases separately; results were similar (Supplementary Table 1). We also used parameter penalized quasi-likelihood (PQL) methods in separate analyses based on sex and the results were similar to when using MQL methods (Supplementary Table 2).

To explore whether the effect of linking social capital remains significant after adjustment for smoking history, we ran a sensitivity analysis using data from the Military Conscription Register and the Swedish Medical Birth Register and the results were almost identical. In the full model, individuals living in neighborhoods with low linking social capital were more likely to have lung cancer compared with those living in neighborhoods with high linking social capital (Supplementary Table 3: OR = 1.44; 95% CI = 1.03–2.03).

## 4. Discussion

The main finding of this study is that the ORs for lung cancer incidence and mortality was higher for both men and women in neighborhoods with low linking social capital and after the inclusion of the individual- and familial-level factors. In addition, the crude OR implies that individuals exposed to low social capital have an increased risk of developing lung cancer (47% of men and 61% of women). The crude OR is often important for decisions concerning the distribution of health care resources, whereas the adjusted ORs are significant in determining potential mechanisms.

This is the first study that elucidates the association between social capital and lung cancer, because previous studies used overall cancer mortality rather than cause-specific cancer mortality, such as lung cancer as an outcome variable. For example, a previous study from the US found no association between neighborhood social capital and neighborhood cancer mortality [23]. A study from New Zealand also found that social capital was not associated with cancer mortality [27]. Thus, our results were not directly comparable to those of other studies. Rather, our findings extend these findings because the present study

**Table 2**

Odds ratios (OR) and 95% confidence intervals (CI) for lung cancer, including incident and mortality cases, in men: Results of multi-level logistic regression models.

| | Model 1 | | | Model 2 | | | Model 3 | | | Model 4 | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | OR | 95% CI | | OR | 95% CI | | OR | 95% CI | | OR | 95% CI | | P-value |
| Linking social capital (ref. high) | | | | | | | | | | | | | |
| Low | 1.47 | 1.37 | 1.57 | 1.73 | 1.61 | 1.86 | 1.44 | 1.34 | 1.55 | 1.37 | 1.27 | 1.47 | < 0.001 |
| Intermediate | 1.17 | 1.10 | 1.25 | 1.27 | 1.19 | 1.36 | 1.18 | 1.11 | 1.26 | 1.17 | 1.09 | 1.24 | < 0.001 |
| Age | | | | 1.12 | 1.11 | 1.12 | 1.12 | 1.12 | 1.12 | 1.11 | 1.11 | 1.11 | < 0.001 |
| Family income (ref. high income) | | | | | | | | | | | | | |
| Middle-high income | | | | | | | 1.21 | 1.14 | 1.28 | 1.16 | 1.09 | 1.24 | < 0.001 |
| Middle-low income | | | | | | | 1.20 | 1.12 | 1.27 | 1.11 | 1.04 | 1.18 | 0.001 |
| Low income | | | | | | | 1.29 | 1.21 | 1.38 | 1.19 | 1.11 | 1.27 | < 0.001 |
| Marital status (ref. married/cohabiting) | | | | | | | | | | | | | |
| Never married, widowed, or divorced | | | | | | | 1.47 | 1.40 | 1.53 | 1.35 | 1.29 | 1.42 | < 0.001 |
| Immigrant status (ref. born in Sweden) | | | | | | | 0.64 | 0.52 | 0.79 | 0.64 | 0.52 | 0.79 | < 0.001 |
| Education attainment (ref. > 12 years) | | | | | | | | | | | | | |
| ≤9 years | | | | | | | 1.58 | 1.49 | 1.67 | 1.52 | 1.44 | 1.61 | < 0.001 |
| 10–12 years | | | | | | | 1.41 | 1.33 | 1.49 | 1.35 | 1.27 | 1.43 | < 0.001 |
| Region of residence (ref. large cities) | | | | | | | | | | | | | |
| Southern Sweden | | | | | | | 0.79 | 0.75 | 0.83 | 0.81 | 0.77 | 0.85 | < 0.001 |
| Northern Sweden | | | | | | | 0.59 | 0.55 | 0.63 | 0.62 | 0.57 | 0.66 | < 0.001 |
| Mobility (ref. not moved) | | | | | | | 1.15 | 1.08 | 1.22 | 1.08 | 1.02 | 1.15 | < 0.001 |
| Family history (ref. no) | | | | | | | 1.99 | 1.86 | 2.13 | 1.91 | 1.78 | 2.04 | < 0.001 |
| Hospitalization of chronic lower respiratory disease (ref. no) | | | | | | | | | | 3.52 | 3.31 | 3.74 | < 0.001 |
| Hospitalization from alcoholism and alcohol-related liver disease (ref. no) | | | | | | | | | | 1.65 | 1.53 | 1.78 | < 0.001 |
| Tobacco abuse (ref. no) | | | | | | | | | | 3.83 | 3.37 | 4.36 | < 0.001 |
| *Variance (S.E.)* | *0.093 (0.014)* | | | *0.127 (0.015)* | | | *0.075 (0.014)* | | | *0.069 (0.014)* | | | |
| *Explained variance (%)* | *18* | | | *− 12* | | | *34* | | | *39* | | | |
| *Intra class correlation* | *0.027* | | | *0.037* | | | *0.022* | | | *0.021* | | | |

Model 1: crude model.

Model 2: adjusted for age and sex.

Model 3: adjusted for age, sex, family income, marital status, country of birth, education, region of residence, and family history.

Model 4: adjusted for age, sex, family income, marital status, country of birth, education, region of residence, mobility, family history, and comorbidities.

**Table 3**

Odds ratios (OR) and 95% confidence intervals (CI) for lung cancer, including incident and mortality cases, in women: Results of multi-level logistic regression models.

| | Model 1 | | | Model 2 | | | Model 3 | | | Model 4 | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | OR | 95% CI | | OR | 95% CI | | OR | 95% CI | | OR | 95% CI | | P-value |
| Linking social capital (ref. high) | | | | | | | | | | | | | |
| Low | 1.61 | 1.50 | 1.73 | 1.66 | 1.55 | 1.78 | 1.41 | 1.31 | 1.51 | 1.32 | 1.23 | 1.42 | < 0.001 |
| Intermediate | 1.17 | 1.10 | 1.24 | 1.19 | 1.12 | 1.27 | 1.12 | 1.05 | 1.19 | 1.10 | 1.03 | 1.17 | 0.004 |
| Age | | | | 1.10 | 1.10 | 1.10 | 1.09 | 1.09 | 1.10 | 1.09 | 1.09 | 1.09 | < 0.001 |
| Family income (ref. high income) | | | | | | | | | | | | | |
| Middle-high income | | | | | | | 1.05 | 0.98 | 1.11 | 1.02 | 0.96 | 1.08 | 0.549 |
| Middle-low income | | | | | | | 1.04 | 0.98 | 1.11 | 0.96 | 0.90 | 1.03 | 0.230 |
| Low income | | | | | | | 0.87 | 0.81 | 0.93 | 0.81 | 0.76 | 0.87 | < 0.001 |
| Marital status (ref. married/cohabiting) | | | | | | | | | | | | | |
| Never married, widowed, or divorced | | | | | | | 1.39 | 1.33 | 1.46 | 1.29 | 1.23 | 1.34 | < 0.001 |
| Immigrant status (ref. born in Sweden) | | | | | | | 0.58 | 0.47 | 0.73 | 0.59 | 0.47 | 0.73 | < 0.001 |
| Education attainment (ref. > 12 years) | | | | | | | | | | | | | |
| ≤9 years | | | | | | | 1.97 | 1.85 | 2.10 | 1.85 | 1.74 | 1.97 | < 0.001 |
| 10–12 years | | | | | | | 1.69 | 1.59 | 1.80 | 1.61 | 1.52 | 1.71 | < 0.001 |
| Region of residence (ref. large cities) | | | | | | | | | | | | | |
| Southern Sweden | | | | | | | 0.87 | 0.82 | 0.91 | 0.90 | 0.85 | 0.94 | < 0.001 |
| Northern Sweden | | | | | | | 0.72 | 0.68 | 0.77 | 0.76 | 0.71 | 0.81 | < 0.001 |
| Mobility (ref. not moved) | | | | | | | 1.12 | 1.06 | 1.19 | 1.06 | 1.00 | 1.13 | 0.036 |
| Family history (ref. no) | | | | | | | 2.23 | 2.09 | 2.38 | 2.13 | 1.99 | 2.27 | < 0.001 |
| Hospitalization of chronic lower respiratory disease (ref. no) | | | | | | | | | | 4.06 | 3.83 | 4.30 | < 0.001 |
| Hospitalization of alcoholism and related liver disease (ref. no) | | | | | | | | | | 2.19 | 1.97 | 2.42 | < 0.001 |
| Tobacco abuse (ref. no) | | | | | | | | | | 3.70 | 3.24 | 4.23 | < 0.001 |
| *Variance (S.E.)* | *0.087 (0.014)* | | | *0.086 (0.014)* | | | *0.049 (0.013)* | | | *0.042 (0.013)* | | | |
| *Explained variance (%)* | *29* | | | *30* | | | *60* | | | *66* | | | |
| *Intra class correlation* | *0.026* | | | *0.025* | | | *0.015* | | | *0.013* | | | |

Model 1: crude model.

Model 2: adjusted for age and sex.

Model 3: adjusted for age, sex, family income, marital status, country of birth, education, region of residence, and family history.

Model 4: adjusted for age, sex, family income, marital status, country of birth, education, region of residence, mobility, family history, and comorbidities.

focused on specific cancer, i.e., lung cancer, and showed significant associations with social capital. For a better understanding of the association between social capital and cancer, we recommend that future studies should focus on specific diagnosis of cancer and use adjustment variables that are appropriate confounders for each type of cancer.

The causal inferences between linking social capital and lung cancer are not fully understood, and several possible mechanisms could have affected our findings. Psychological distress could be a possible mediator between linking social capital and lung cancer. Previous studies have suggested that lower social capital is associated with psychological distress [28,29]. Our results could also be affected by differences in the accessibility to healthcare facilities. However, our research group performed a nationwide study and found that underserved neighborhoods had better access to all type of resources, including pharmacies/drug stores, public hospitals, health care centers, and dentists, which suggests that neighborhood differences in health in Sweden are not explained by a lack of health resources [30]. Linking social capital may reflect how well the society is organized at the neighborhood level. One possible explanation for our results is therefore that individuals living in neighborhoods with higher linking social capital have the capability to maintain social order, that is, to step in and intervene when they witness deviant behavior of other people [9]. Although this theory originated in criminology to explain community variations in the occurrence of vandalism, it is equally applicable and relevant to the prevention of underage smoking, drinking or drug abuse [9,31]. Another possible explanation is that individuals living in neighborhoods with higher linking social capital could spread health-related information as well as good health-related behavior more quickly owing to well-functioning networks of people within the neighborhood [9]. For example, previous research conducted in the United States found that smoking cessation was triggered by the behavior of others, i.e., groups of interconnected people may stop smoking in concert, and smokers are increasingly marginalized socially [32]. Further studies are needed to examine these mechanisms through assessing the relationship of residents within neighborhoods.

The present study has some limitations. First, the study used linking social capital measured by neighborhood voting rates as a way to simplify this multidimensional concept. However, a consensus has not yet been established as to which proxy of social capital is the most valid. Second, our results could be influenced by other unmeasured confounders, such as smoking history. However, our analyses included tobacco abuse and hospitalization of chronic lower respiratory disease as an attempt to adjust for smoking history. In addition, the results of the sensitive analysis that included smoking history showed similar associations. Third, the Modifiable Area Unit Problem has previously been acknowledged as a potential limitation when using aggregated data [33]. However, the SAMS boundaries in our study were drawn to include similar types of buildings in a defined geographic unit, which implies that SAMS neighborhoods are comparatively homogeneous in terms of socioeconomic structure.

The present study also has key strengths. First, this is the first large-scale multilevel study that examined the potential effect of linking social capital on lung cancer, after adjustment for a comprehensive set of individual- and familial-level factors as well as family history of lung cancer. Second, our study was based on the entire Swedish population, with a total of 2,123,707 men and 2,046,174 women living in 8398 small neighborhoods, each with around 1000 residents. The use of small neighborhoods is advantageous to examine the effect of social capital on health outcome according to the review on social capital [34]. Third, our outcome variable (lung cancer) and exposure variable (linking social capital) were obtained from different sources, which eliminate spurious associations due to same-source bias. Finally, the prospective design of our study is more likely to reflect causality than a cross-sectional or retrospective design when used in evaluating the effect of an exposure, which is the level of neighborhood linking social capital.

## Authorship contribution statement

TH, XL, JS, KS worked on conception of the study; XL analysed the data; TH, XL, JS, KS contributed to the interpretation of the data; TH drafted the paper; XL, JS, KS worked on further drafting and revising the paper critically. All authors read and approved the final manuscript.

## Conflict of interest

None.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.canep.2019.05.005.

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