An ERA-based study of built environment factors affecting lung cancer incidence rate among Chinese women

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Abstract: Objective：Application of ERA methods to investigate the atmospheric pollution and built environment factors influencing lung cancer incidence rate in Chinese women. METHODS: Lung cancer incidence rate among Chinese women at 339 cancer registries were obtained from the China Cancer Registry Annual Report 2017, air quality and built environment data were obtained from the Greenpeace and China Construction Yearbook. After multiple covariates variables were eliminated, an exploratory regression analysis was performed using the world standardized population incidence rate as the dependent variable. Air quality and built environment factors as the independent variable. Results: Shandong Peninsula, Hebei and Liaoning are high incidence rate areas of female lung cancer in China, with significant regional aggregation. In addition to air quality factors such as industrial smoke emission data, the association between built environmental factors such as urbanization rate, development LUI, population density and greening coverage of built-up areas and female lung cancer incidence rate is statistically significant. CONCLUSION: In addition to air quality factors, urban spatial factors can also significantly affect respiratory health. The LUI is positively while urbanization rates and population density are negatively correlated with the incidence rate of lung cancer. The role of green space for respiratory health has not been proven. In addition, there is little relationship between income and health, and similar findings are found for indicators such as the public transportation and roads network.

Keywords: Exploratory regression analysis; built environment; influencing factors; incidence rate for female lung cancer

1 Introduction

Lung cancer is a malignant tumour that occurs in the lungs. The tumour of respiratory organs (trachea, bronchus, and lung), represented by lung cancer is one of the most predominant cancer in China at present (He Jie and Chen Wanqing, 2017). The incidence rate and mortality rates of lung cancer in both men and women are increasing year by year. The development of lung cancer is a complex process with many causative factors, complex etiologic and multi-stage development. The risk of lung cancer is somewhat related to tobacco, but air pollution is a risk factor that cannot be ignored. However, there are very few studies on air pollution and lung cancer in China. Little of them have addressed the spatial dimension of air pollution. The objective of this study was to determine the effect of air pollution and built environment factors on lung cancer incidence rate.

The smoking rate in China is 50.2% for males over 15 years of age. Counterpart the smoking rate is 2.8% among females which is much lower than the international level and lower than that of developed countries. But curiously, the incidence rate of lung cancer among females in China is at a high level in the world, suggesting that other risk factors other than smoking may exist (Ma Guangsheng et al., 2005).

2 Scope of the study

2.1 Scope of the study

This paper focuses on the causal link between built environment factors and lung cancer and its significance. In order to minimize the influence of personal lifestyle factors such as smoking and alcohol abuse, only the incidence rate of lung cancer in Chinese women was included in this study.

2.2 Data source and methods

2.2.1 Incidence rate of lung cancer among women by province

We used the most recent incidence data from the China Cancer Registry Annual Report 2017 which published by the Chinese National Cancer Centre. To eliminate the interregional effects, we selected the age-standardized (Segi population) incidence rate as the study indicator.

The data of *The China Cancer Registration Annual Report 2017* is reported from qualified 339 cancer registries in 129 urban and 210 rural in China covered 288,243,347 populations. Because of the uneven distribution of registries and the complicated administrative divisions in China, some registries belong to cities or counties, while some belong to prefecture-level cities, the scale of registries is not consistent and overlapping. It is not suitable for comparison at the city scale. Therefore, this study averaged the data from the sampling points according to the provinces to obtain the provincial incidence rate data of lung cancer among Chinese women (Figure 1).

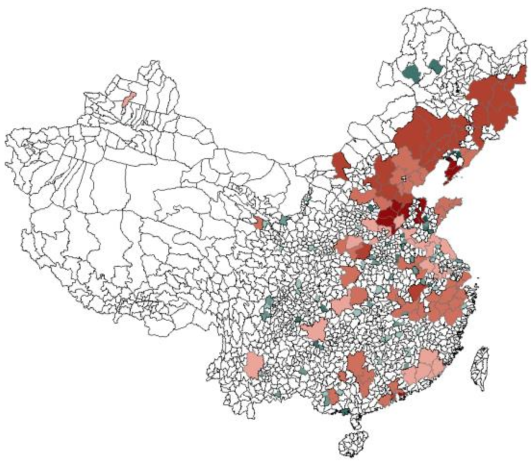

Figure 1 Distribution of 339 cancer registries in China (2014)

2.2.2 Air quality

In this study, two indicators were selected to characterize air quality: the air quality index（AQI）and industrial dust emissions. The AQI is a quantitative description of air quality. It includes six major pollutants: PM2.5, PM10, SO_2, CO, O_{3fubu} and NO_2. Chinese PM2.5 data was first released in 2014. The data is unstable and small. Considering that air quality tends to stabilize in a short term and the registration time is lagging behind the actual time of diagnosis. This study uses the 2015 *Average daily air quality of 366 key cities 2015* published by Greenpeace, an international environmental protection organization. It include a total of 133,436 data. Each province takes the annual average of all cities within range as air quality indicator.

2.2.3 Built environment factors

Built environment factors are selected for indicators such as land use intensity(LUI), greening coverage ratio, total number of buses per 10,000 persons, road area per capita and population density.

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The LUI comes from the report *Land Use Evaluation Ranking of Provinces and Municipalities in China* published by the Ministry of Land and Resources of China in 2018, with the highest value being Shanghai, where the LUI reached 36.89%, 5.26 times the national average, and the lowest value being Tibet (0.27%). Data on the Greening coverage ratio, total number of buses per 10,000 persons, road area per capita, and population density are from the *China Urban Statistics Yearbook 2015*. Data on the urbanization rate and per capita income for each province are from public data on the China National Bureau of Statistics website.

2.2.4 Data normalization

The incidence rate of lung cancer is adjusted by age-standardized (Segi population,1960). For convenience, *the incidence rate of lung cancer adjusted by age-standardized (Segi population)* is simplified by *the incidence rate of lung cancer* below. Because industrial smog and dust emissions, per capita income, population density are too large and differ from other indicators by orders of magnitude, they are normalized by logarithms.

3 Methodology

3.1. Model construction

A literature review on healthy cities published in 2005-2009 by the WHO European, *Evidence Review on the Spatial Determinants of Health in urban setting* found that the main influences of urban planning on health are four aspects: land use, transportation, green space and urban design (Grant and Braubach, 2010). In this study, the incidence rate of lung cancer among women in a provinces were selected as the dependent variable, the land use LUI, the road area per capita, and the greening coverage of built-up areas were selected as the independent variables corresponding to the land use, transportation, and green space factors. In order to avoid subjective difference of urban design, an alternative approach is adopting, i.e. urbanization rate and the total number of buses per 10,000 persons as the more observant dependent variables. Because atmospheric pollution factors have a direct impact on respiratory health, the AQI and industrial smog and dust emissions were selected as indicators as a separate factor of influence. At the same time, socioeconomic status also has an impact on health(Mitchell and Popham, 2008; Zhang, 2013). This study uses regional per capita income participation modelling (Figure 2).

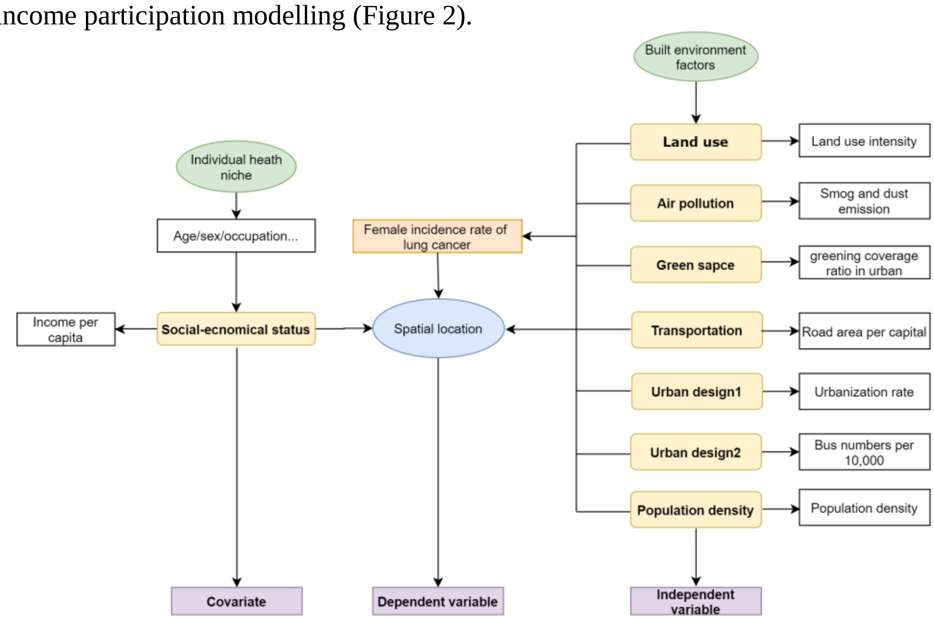

Figure 2 Model of female lung cancer incidence rate and built environment factors

3.2. Multi-collinearity diagnosis

To exclude the effect of multi-collinearity, the data were imported into SPSS 22.0 with female lung cancer incidence rate as the predictor variable and air quality index as the independent variable.

Table 1 Summary of multiple regression models

Model	R	R-squared	Adjusted R-squared	Standard Estimate Error	Model Summary		
					Regression	Residual	Significance
1	.741a	.549	.412	128.513	462727.201	379858.260	.005b

a. Predictor variables: (constant), NO2, O3, SO2, CO, PM10, PM2_5, AQI b. Dependent variable: Female lung cancer incidence rate(segi)

The adjusted R-square of the results reached 0.412, with a significance test P-value <0.01, rejecting the null hypothesis that there is a strong correlation between lung cancer incidence rate in women and air quality. However, it was also found that the variance inflation factor (VIF) between AQI and PM2.5 and PM10 was >25. Only one of them could be retained. Considering that PM2.5 particles can penetrate deep into the alveoli, the harm is greater and more well-known(Mitchell and Popham, 2008; Zhang, 2013), the PM2.5 indicator were retained. Other variables with significant P values greater than 0.05 were also excluded. This way the air quality variable retains only PM2.5 and more representative.

Table 2 AQI Multiple regression model coefficients

		Non-standardized coefficient		Standardized coefficient			Common linear statistics	
		B	Standard Error	Beta	t	Significance	Tolerate	VIF
1	(constant)	3.722	215.692		.017	.986		
	AQI	-30.448	10.463	-3.599	-2.910	.008	.013	78.032
	PM2_5	30.009	7.895	2.791	3.801	.001	.036	27.507
	PM10	9.509	4.544	1.500	2.093	.048	.038	26.221
	SO2	4.908	3.073	.334	1.597	.124	.449	2.225
	CO	-17.607	15.911	-.272	-1.107	.280	.325	3.079
	O3	8.827	4.338	.418	2.035	.054	.465	2.151
	NO2	-3.967	5.151	-.222	-.770	.449	.236	4.236

a. Dependent variable: Incidence rate of female lung cancer (Segi)

3.3 Exploratory regression analysis

Exploratory regression analysis (ERA) is a data mining tool to understand which models can be passed by all necessary Ordinary Least Square (OLS) diagnosis. Using ERA tools, it is possible to perform an exhaustive analysis of all combinations of covariates to find the OLS model that meets the set conditions and has the best explanatory effect on dependent variable. And to determine whether the influencing factor is significant and the magnitude of the effect. The use of ERA tools has advantages over other methods of evaluating model performance based solely on adjusted R^2 values. It can be greatly increased the chances of finding the best model by evaluating all possible combinations of candidate explanatory variables.

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4 Results

4.1 Statistical characteristics of the incidence rate of lung cancer among women in China

After statistics and analysis, it can be seen that the national average incidence rate of lung cancer is 171.06 per 100,000 for women and 360.72 per 100,000 for men, which is 2.1 times that of women. The incidence rate of lung cancer among Chinese women was 0.34 at the minimum(Tibet) and 423.95 per 100,000 (Shandong) at the maximum, with a mean value of 119.63 and a standard deviation of 119.40 per 100,000 persons. In 2014, the five provinces with the highest incidence rate of lung cancer among women in China were Shandong, Hebei, Liaoning, Henan and Anhui(Figure 3).

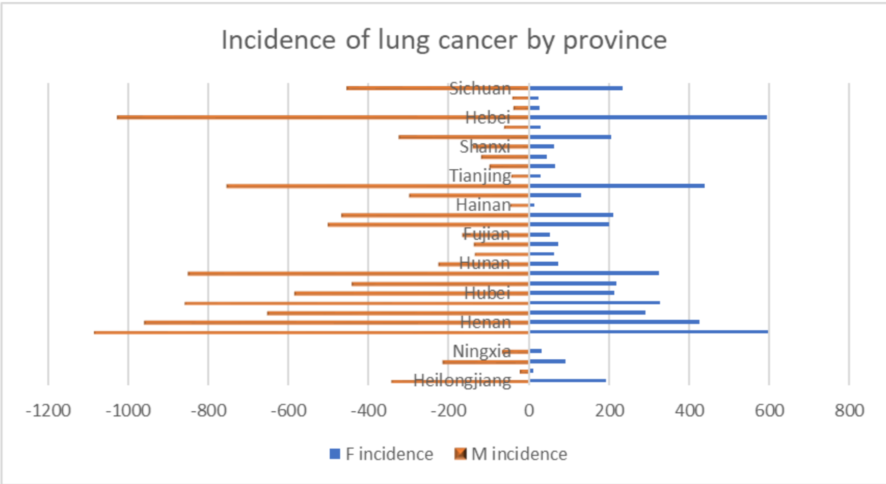

Figure3 Incidence rate of lung cancer by province (2014)

4.2 Spatial distribution of lung cancer incidence rate among women in China

Comparing the spatial distribution of the incidence rate of lung cancer among men and women in China in 2014, it can be seen that the high incidence rate of lung cancer among women is basically the same as that of men, with Hebei and Liaoning being the high incidence rate of lung cancer among women on the Shandong Peninsula, and Xinjiang and Tibet being relatively rare, with a clear spacial and regional concentration (Figure 4).

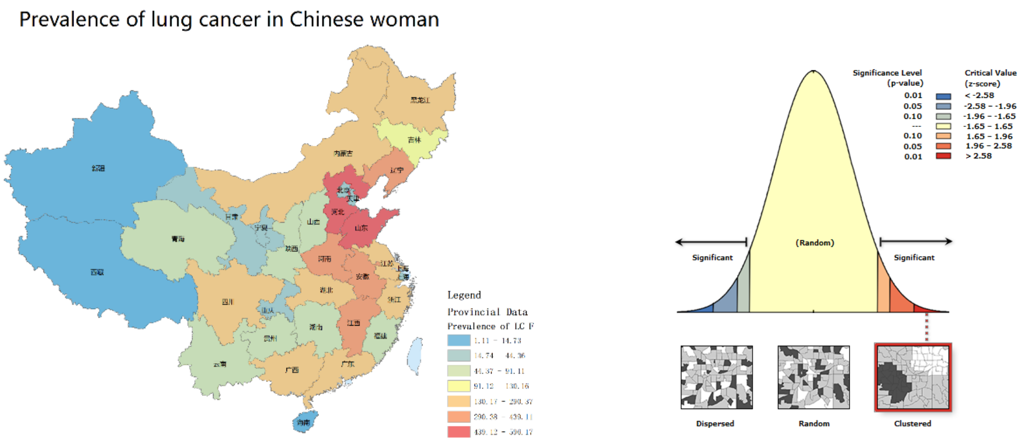

Figure 4 Spatial distribution of lung cancer incidence rate among Chinese women

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4.3 Results of exploratory regression analysis

The data were imported into Arcgis 10.2 software and analysed using the "exploratory regression analysis" tool. The female lung cancer incidence as the dependent variable, and PM2.5, greening coverage of built-up areas, urbanization rate, land use LUI, road area per capita, total number of buses per 10,000 persons, log population density, log smog and dust emission, log per capita income were selected as the explanatory variables. After operation, it can be seen that 466 models were calculated, 100% passed the VIF test, 409 models passed the Jarque-Bera test, 21 models passed the space autocorrelation (Moran's I value test), 4 models passed the model significance (95% confidence range), but only 2 models passed all the model set threshold, and only 1 model included all the independent variable. In order to fully show the effect of the variables, it is also included in the table below.

Table 4: Summary list of models

Model number	AdjR^2	AICc	JB	K(BP)	VIF	SA	Variables in Model
1	0.44	395.45	0.36	0.33	2.51	0.30	-URBAN** +LUI** + FROG***
2	0.56	392.52	0.67	0.22	2.79	0.50	+GREEN** -URBAN*** +LUI*** -POP** + FROG***
3	0.51	407.48	0.91	0.17	7.00	0.32	+FROG*** +PM2.5 +GREEN** +BUS +LUI** +INCOME -URBAN** -ROAD -POP*

Variable abbreviations.

Adj R^2 Adjusted R-squared

AICc Akaike information criterion

JB Jarque-Bera p-value

K(BP) Koenker's studentized Breusch-Pagan statistic

VIF Maximum variance inflation factor

SA Global Moran's I value

Variable sign (+/-)

Variable significance (* = 0.10, ** = 0.05, *** = 0.01)

The adjusted R-squared coefficient of Model 2 reaches 0.56, which is much larger than the adjusted R-squared coefficient of 0.44 in Model 1. The Akaike information criterion (AIC) value of 392.52 in Model 2 is smaller than the AIC value of 395.45 in Model 1. Model 2 models is better than Model 1. Model 2 include five explanatory variables: industrial smog and dust emission (+***), urbanization rate (-***), land use LUI (+***), population density (-**), greening coverage of built-up area (+**).

Model 3 contains all explanatory variables, with VIF values all below the 7.5 threshold and no significant collinearity between variables. From the significance of the variables, the explanatory variables are, in descending order of significance: industrial smog and dust emissions (+), LUI of land use (+), urbanization rate (-), greening coverage of built-up areas (+), population density (-), PM2.5, total number of buses per 10,000 persons, road area and income per capita are not significant.

5 Discussion

It has been shown that the main risk factors for lung cancer come from autosomal recessive heredity and lifestyle habits (e.g. smoking, alcoholism). A meta-analysis conducted by School of Medicine in Jinan University collected relevant studies on lung cancer risk factors in China from 2006-2016 and showed that exposure to toxic and harmful substances, history of respiratory disease, smoking and passive smoking (secondhand smoke) are the most important risk factors for lung cancer incidence (Zeng Luyi et al., 2018). The International Agency for Research on Cancer (IARC) clearly stated in 2013 that air pollution is a carcinogen. According to the study of American Cancer Society

(ACS), each 10μg/m^3 increase in PM2.5 increased lung cancer mortality by 8% (Chen Bingheng et al., 2007). Existing studies have proposed some hypotheses that built environment factors has a deepen impact on air quality and the distribution of atmospheric pollutants (Brokamp et al., 2019; The, 2019; Zhang et al., 2019). Changes in built environment can lead to regional changes in air quality, which in turn affect respiratory health (Dong Chongya and Kang Xiaoping, 2014). Industrial planning can also affect the distribution and state of air pollution. Smog and dust emissions from enterprise production, respirable particulate matter, i.e. PM2.5 and PM10 are significantly associated with all types of lung cancer(Clougherty and Kubzansky, 2009). It has been studied that every 10 μg/m^2 increase in PM10 increases the risk of lung cancer by 22% (Chen et al., 2016) while every 10 μg/m^2 increase in PM2.5 increases cardiovascular disease and lung cancer mortality by 6% and 8% respectively (C Arden et al., 2002). People live near high traffic roads are adversely affected by both noise and air pollution (Babisch, 2008; Dzhambov et al., 2019).

According to the results of model 2, it can be seen that the variable of industrial smog and dust emission in the air quality index has a high correlation with the incidence rate of lung cancer among Chinese women ($P<0.01$, significance is 100%) and PM2.5 is also significant, but the stability is weaker than the industrial smog and dust emission. The air pollution level has a stronger correlation with the incidence rate of lung cancer among Chinese women, supporting the existing theoretical hypothesis (Cardoso et al., 2019).

Among built environment factors, previous studies have concluded that high density of built environments means that the distance between destination and departure is short and people tend to choose to travel by foot or bicycle, which is good for their health. Not only do green spaces increase the walkability index, but green plants can absorb atmospheric pollutants. The incidence rate of respiratory diseases was significantly lower in the greener regions than in the poorer ones. Spontaneously green space have a significant impact on the respiratory health (Crouse et al., 2019; Dzhambov et al., 2019; Laurent et al., 2019). In addition, socioeconomic status is also considered has an impact on respiratory health (Clougherty and Kubzansky, 2009; Morello-Frosch and Shenassa, 2006).

5.1 Implications for cancer prevention in China from the view of built environment

The results of our model showed a positive correlation between LUI and lung cancer incidence rate, which is consistent with the results of existing studies. The LUI is too high, which means that the density of buildings within the site is high and the number of high-rise buildings is large, more convenient for living. However, i.e. building sites occupy a large amounts of land, squeezing out green and public space. Overcrowding has been shown to be an important built environment factor for stress-induced chronic disease (Clougherty and Kubzansky, 2009). High intensity of land use also contributes to high traffic volumes in the area. The resulting noise (Welch et al., 2013) and air pollution (Beelen et al., 2008) cannot be underestimated.

Urbanization rate and population density are negatively correlated with the incidence rate of lung cancer among Chinese women, which differs from the findings of some existing studies (Dong Chongya and Kang Xiaoping, 2014). But it is consistent with a research paper written by National Cancer Centre. In this paper, it was concluded that residents of rural areas had significantly higher incidence and mortality rates for all cancers combined than urban residents (213.6 per 100,000 vs 191.5 per 100,000 for incidence; 149.0 per 100,000 vs 109.5 per 100,000 for mortality, respectively). And we believe that it is also related to the larger sample size. The provinces with higher urbanization rate in China are located in the southeastern coastal areas. These areas are more urbanized and the economy is more developed, so public services are better, the residents are more educated. According to a study by Huazhong University of Science and Technology it is believed that the smoking rate in the eastern region has declined somewhat in the past decade, while the smoking rate in the central and western regions has remained constant. Furthermore, smoking rates are consistently relatively higher in rural areas compared to urban areas (Minghuan et al., 2018), which may explain some of the problem.

In addition, the greening coverage ratio of built-up areas was positively correlated with the incidence rate of lung cancer in women, which is also somewhat different from the general perception and some existing studies. This may be twofold, the first is that the relationship between the amount of green space and health outcomes is insignificant. A study in the UK (2017) showing that green space in low-income suburbs is less accessible and of poorer quality. The health outcomes in these deprived areas tend to be worse than average. The reason may be that poor quality green spaces, although numerous, are not sufficient to offset the health problems of the low-income population, or that poor quality green spaces are actually harmful to health (Mitchell and Popham, 2007). A study in the Netherlands also showed that there was no significant link between the amount of green space in the living environment and health. People who had more green space in their living environment spent more time on gardening, resulting in less physical activity and less time, which in turn was detrimental to health (Maas et al., 2008).

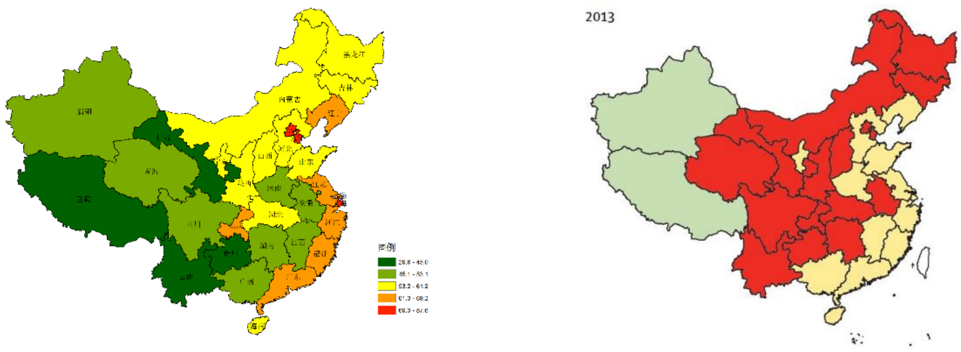

Figure 5: Comparison of urbanization rate and smoking rate by province in China

Source: left: self drawn right: *Trends in smoking incidence rate and implication for chronic diseases in china: serial national cross-sectional surveys from 2003 to 2013*

Secondly, there may be a problem with our choice of green space indicators. The calculating of Greening coverage ratio of built-up areas is relatively rough and broad. It reflects the ecological and environmental protection status of a region. Protective green space, production green space and green planting on roofs is all included in it. In addition, the Greening coverage ratio of urban built-up areas in various provinces is only an average, the difference between rural and urban living environments is not reflected. Resulting that the greening coverage ratio of built-up areas in various provinces do not differ much, therefore, the Greening coverage ratio of built-up areas may not be suitable as an indicator of the greening rate of living environments.

The total number of buses per 10,000 persons and road area per capita indicators are not significant. It may imply that lung cancer pathogenesis is different from chronic diseases such as obesity and that physical activity is not a risk factor for respiratory health. The per capita income indicator is the least significant of the explanatory variables, indicating that the incidence rate of lung cancer among China women is also not associated with the socio-economic status of the individual.

5.2 Limitation

Although the relationship between the incidence rate of lung cancer and built environment factors is discussed to some extent, the analysis is not in-depth. The study only confirmed the influence of built environment factors on the incidence rate of lung cancer and which factors have a greater influence and which factors have not yet been found to have a definitive effect. Although some weak causal links were found, the spatial metrology model established may be low according to the usual validity criteria. On the one hand, it was limited to the author's academic level, on the other hand, the research on healthy human settlement is still a fairly young field. There are a lot of non-linear compound relationships between urban space and respiratory health. Maybe the general linear mathematical model cannot be better simulated and research methods need improvement.

Even though existing big data and mathematical modelling techniques have improved dramatically over the past, healthy human settlements research remains a considerable challenge. This is largely constrained by the systemic complexity inherent in the field of public health and healthy human settlements. Analytical techniques based on linear multiple regression methods may not be the best approach for the complex mega-system of healthy human settlements.

The third, greening coverage ratio of built-up areas indicator may not suitable for our study because of roughness. However, the statistical calibre of the various types of publicly available statistical information are all based on the "Greening coverage ratio of built-up areas". For the time being, due to the limited availability of data, the study can only be replaced by an indicator of greening coverage ratio in built-up areas. So the robustness of this conclusion has yet to be proven and this gap will be filled in the follow-up study.

6 conclusion

The results show that industrial smog and dust emissions and PM2.5 are significantly health risks factors for respiratory health. They must be combat and control. In addition to air quality factors, built environment factors are also significantly respiratory health risk factors. The LUI is positively correlated with the incidence rate of lung cancer in women, which is detrimental to all residents' health. Urbanization rates and population density are negatively correlated with the incidence rate of lung cancer. That is to say, perhaps high-quality medical services are a deterrent to lung cancer. The role of green space for respiratory health has not been proven. In addition, there is little relationship between income and health, and similar findings are found for indicators such as the public transportation and roads network. However, the existing research is far from in-depth and rich, and further study and optimized research methods is needed.

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