The Effect of Air Pollution and Temperature on Pulmonary Function in Healthy People in Xi’an, China

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Research

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Abstract

Background

Temperature and air pollution has been reported to be associated with respiratory diseases. However, little is known about these effects on healthy people, and the potential interaction between the two factors is still uncertain. This study aims to estimate the effects of air pollution combined with temperature on lung function in healthy people.

Methods

The lung function of 132 healthy people was measured in Xi'an, Shaanxi province of Northwest China in summer and winter. Meanwhile, the daily concentrations of air pollution and temperature were obtained from monitoring stations. Statistical analyses were assessed by generalized estimating equations (GEEs).

Results

Every 10μg/m 3 increase of PM 2.5 concentration, PEF change amount is -0.007L/min (95% CI: -0.013, -0.001 L/min), FEV1 is -0.004 (95% CI: -0.006, -0.001 L/min),FEF25-75% is -0.002(95% CI: -0.003, -0.001 L/min) FEV1/FVC change amount is -0.074 L/min (95% CI: -0.115, -0.033 L/min). Lag effects showed that Lag0 of FEV1, FEV1/FVC and FEF25-75% were more strongly associated with PM2.5. There was no significant interaction between PM 2.5 and temperature.

Conclusions

Our findings indicate that PM 2.5 has an acute adverse effect on lung function in winter, and the lung function is less affected by temperature change in Xi'an.

Introduction

The pulmonary function test (PFT) is an effective tool to evaluate the respiratory system including airway resistance, lung compliance and diffusing capacity [1–3]. Clinically, it is a golden standard for physicians to diagnose some lung diseases, such as chronic obstructive pulmonary disease (COPD), asthma[4, 5].However, lung function is affected by many inner and extrinsic factors. Especially, extrinsic factors may damage the lung function.

Many studies have founded that climate change is related to respiratory health. TORCH (Towards a Revolution in COPD Health) studies showed that COPD exacerbations and hospitalization were more frequent in winter[6].Studies have also reported the acute effects of air pollution in patients with respiratory diseases[7–9].Epidemiological studies have reported associations between particulate matter or temperature and human health[10].However, the results are inconsistent even conflicted. Zhang and collages[11]showed that $PM_{2.5}$ had an acute adverse effect on lung function in healthy people and had

an antagonistic effect on temperature. Zheng[12]also performed a study on temperature and air pollution on lung function, but come to the opposite conclusion.They founded synergistic effects of PM and high temperatures on cardiopulmonary mortality. Therefore, it is necessary to clarify the relationship between air pollution, temperature and lung function. Besides, few studies have investigated the effects in healthy adults, and even fewer have examined the effects of air pollution combined with climate on lung function simultaneously.

This study therefore aimed to investigate the effects of temperature and air pollution on lung function among healthy people in Xi’an.

Materials And Methods

Study participants and design

The study was conducted in 11 communities of Xi’an city (34°15'44"N,108°56'16"E) with the adult residents by multistage cluster sampling in summer (from July 23th to August 23th) and in winter (November 26th to December 27th). Participation in the survey was voluntary. Participants of 428 from 11 communities were recruited in summer, among these, 296 adults could not be traced in winter, Finally, the remaining 132 were participant in this study. The inclusion criteria for eligible residents were as follows: Adult, and residence>3 years in Xi’an city. Non history of pulmonary, and other chronic disease. The exclusion criterion was history of asthma with. A flowchart is presented in Fig.1

Air pollution exposure

The concentrations of air pollutants and the meterological date were derived from the regional observing system of the ministry of the environment and Meterological Date Sharing Service System, respect, respectively (generated from the 11 state-controlled monitoring stations across Xi’an) over the same duration, China. The averages of $PM_{2.5}$ (particulate matter with an aerodynamic diameter<2.5 μm), nitrogen dioxide (NO_2), and SO_2 concentrations and temperature were included.

Lung function were measured by spirometry

Date on lung function status, including peak expiratory flow rate (PEF, L/sec), forced expiratory volume in 1s(FEV1,L), forced vital capacity (FVC,L), FEV1/FVC and FEF25–75%(L/S) were determined using a portable electronic FGC-A+ spirometer (Spirobank, GTM, Medical International Research, Rome Italy) three times a day.

Statistical analysis

All the statistical date was analysis by SPSS17.0 software (SPSS Inc., Chicago, IL, USA). Pearson correlation was used to analyze the correlation between pollutants concentrations and temperature. The lung function data of these volunteers were self-control in summer and winter. Since there is autocorrelation between the individual lung function data measured repeatedly in this study, the generalized estimating equations (GEES) were using to evaluate the multivariable correlation. This method is a statistical model for fitting the dependent variables of various distributions such as normal distribution and binomial distribution, which can better solve the problems related to the dependent variables in the longitudinal data[13]. The estimated value of parameters was calculated, and the difference was statistically significant when $P < 0.05$).

For parameter estimation, the daily measured pulmonary function of each subject was taken as the dependent variable. Single-pollutant and two pollutant models were used to estimate the effects of $PM_{2.5}$ and temperature on summer and winter, the covariates included (gender, height, season, BMI, 24h average temperature and age). SO_2 or NO_2 was also adjusted for in the two-pollutant models. The effect of increase of pollution concentration per 10ug/m^3 on PEF, FEV1, FVC, FEF25–75 and FEV1/FVC of participants was studied. β value is used as the index to measure the change of lung function index for every 10 ug/m^3 increase of particle concentration. Considering the lag effect of air pollution on health, the impact of pollution level with a lag of 3 days is also analyzed.

Results

Descriptive statistics of exposure and health data

During the year 2018, the basic information of subjects was shown in Table1. Of the 132 participants, 59% of whom were female. Mean age of total participants was 58.23±15.72. The age ranged from 18 to 85. Mean height and weight were 164.07±7.52 and61.34±9.99, respectively. Besides, BMI ranged from 15.63 to 32.46, the mean was 22.75±3.20. The total average PEF and FEV1 were 4.30±1.88 and 2.25±0.76, respectively. The detailed characteristics and FVC, FEV1/FVC and FEF25–75 index were also summarized in Table1.

The associations between temperature and air pollution

Daily average concentrations of air pollutants during this study period are shown in Fig2.Theconcentrations of SO_2, NO_2 and $PM_{2.5}$ were highest on 27th, 22th and 27th Dec. Characteristics of temperature and air pollutants are listed in Table 2. The daily mean temperature was 30.35±2.24℃ in summer and 1.02±3.29℃ in winter. And the daily mean concentrations of $PM_{2.5}$, SO_2 and NO_2 was 31.13±10.07μg/m^3, 7.64±1.39μg/m^3 and 32.78±6.72μg/m^3in summer and 105.56±51.38μg/m^3, 23.58±9.66μg/m^3, 69.45±25.45μg/m^3 in winter, respectively. The three air pollutants were high positively correlated with each other and negative with temperature as shown in Table 3. The correlation

coefficients r of temperature with $PM_{2.5}$, SO_2 and NO_2 were–0.672, –0.790 and –0.706 respectively. The temperature was more related with SO_2. The $PM_{2.5}$ was highly corelated with NO_2(r_s = 0.845).

Analysis of the effects of PM2.5 and Temperature on lung function

Table 4 and Table 5 shows the relationship between air pollutants ($PM_{2.5}$, SO_2 and NO_2), temperature and pulmonary function indexes (PEF, FEV1, FVC, FEF25–75 and FEV1/FVC) in summer and winter, respectively. As shown in Table 4. There was no statistical significance in the effects of air pollutants and temperature on lung function in summer. In winter, for every 10μg/m^3increase of $PM_{2.5}$ concentration, PEF change amount is –0.007L/S (95% CI: –0.013, –0.001), FEV1 is –0.004 (95% CI: –0.006, –0.001),FEF25–75 is –0.002(95% CI: –0.003, –0.001);FEV1/FVC change amount is –0.074 (95% CI:–0.115,–0.033).The difference were all statistically significant (P<0.05).SO_2 and NO_2were selected to establish two-pollutant model respectively. The results showed that after controlling the effect of SO_2, FEV1/FVC change was –0.005 (95% CI –0.009, –0.001) and FVC was –0.007 (95%CI –0.012, –0.002). the results were statistically insignificant(P<0.05), For NO_2, the change of FEV1/FEVC change was–0.054 (95% CI –0.108, –0.001) and the difference is statistically significant(P<0.05).

Additionally, temperature was negative association with and PEF and FEF 25–75 significantly. In the single-pollutant model. A 1℃ increase in temperature was associated with a decrease of 0.40(95% CI–0.071, –0.008) in PEF and an increase of 0.050 (95% CI 0.041,0.058) in FEF25–75. Furthermore, the interactive effects between temperature and $PM_{2.5}$ on PEF, FEV1, FVC and FEV1/FEVC were found to be significantly positive.

Lagged effects of PM2.5 and Temperature on Lung function

Fig. 3 shows the lag effect of $PM_{2.5}$ and temperature on PEF, FEV1and FEV1/FVC. The change in PEF was significantly negatively associated with the concentrations of $PM_{2.5}$. The change was greatest on lag1(–0.006[95% CI:–0.012,–0.001]).For FEV1,FEV1/FEVC and FEF25–75,the effect of $PM_{2.5}$ was greatest on Lag 0(–0.003[95% CI:–0.005,0.000],–0.058[95%CI:–0.095,–0.022 and–0.002[95% CI:–0.003,0.000]), and the different were significantly.

In addition, the cumulative lags of temperature (Lag0) were more corelated with both PFE and FEV1/FVC. The temperature of Lag 1 was related to FEV1 and FEF25–75.

Discussion

Air pollution has become a major threat of public health worldwide, causing up to 7 million premature deaths annually[14, 15]. In recent years, the developing countries in Asia, such as India and China, have

begun large-scale industrialization of urbanization process, so they have been struggling with serious air pollution[16–18]. Besides, Xi'an is located in the lowest part of Guanzhong Basin, which makes it difficult for pollutants to be discharged, just like a "garbage bags"[19, 20]. In addition, as an important industrial center, Xi'an bears the responsibility of poor air quality in the area with serious air pollution. Therefore, the research on the relationship between air pollutants and public health in Xi'an is more important and urgent. Moreover, this study is still in the development stage in Northwest China and has not been studied in Xi'an.

In this study we recruited 132 healthy people from 11 communities in Xi'an city to estimate the air pollution combined with temperature on lung function. We founded that there was a negative correlation between $PM_{2.5}$ and lung function (PEF, FEV1, FVC, FEF25–75 and FEV1/FEVC) in winter. This results is consisting with previous studies conducted in Tangerang and Makassar[21], exposure to $PM_{2.5}$ showed association with decreased lung function. Our study did not find the relationship between $PM_{2.5}$ and lung function in summer. This is more likely that the air pollution is serious in Xi'an, especially in winter, ranking the top of the China. But in summer, the concentration is relatively low. A study conducted by Chen BYin Taiwan of China also demonstrated that the improvement in air quality over time made the correlation between $PM_{2.5}$ and childhood lung function insignificant[22].

However, it seems too hasty to conclude that $PM_{2.5}$ concentration is related to lung function, because the influence of temperature is ignored, which is also an important factor on lung function. In order to make up for this defect. We also analyzed the relationship between temperature and lung function. The results demonstrated that there was no significant correlation between temperature and lung function in both summer and winter. This result contradicts many previous studies. However, a previous study conducted including 5896 residents by Mary B. Ricealso founded that these was no association between temperature and lung function in summer which may be explained by increase outdoor exposures in warm days[23]. McMichaelalso have founded that cold temperatures did not have much effect on respiratory[24]. To explain this conclusion, the following factors may take into consideration. Firstly, Air could be warmed or cooled to constant temperature in nasal cavity and may not stimulate the respiratory system very much on heathy people. Secondly, the seasonal change of behavior is also obvious in Xi'an, the time of outdoor activities increases significantly in summer, which may weaken the influence of temperature on lung function. Furthermore, it is worth noting that the current research focuses on the short-term temperature effect within 30 days, resulting in insignificant temperature change. Lastly, Xi'an has a distinct climate pattern of four seasons per year, corresponding to the subhumid and temperate continental monsoon climate[25, 26]. The average temperature in summer is 30.35±2.24. This is different from that of Zhengmin Qian and Zhang Y, whose studies were performed in Wuhan. Wuhan has been in a high temperature area all the year round [12, 11]. The residents were exposed to high temperatures for longer periods than these in many other cities.

We also analyzed the effect of temperature combined with $PM_{2.5}$ on lung function. We found that three air pollutants ($PM_{2.5}$, SO_2 and NO_2) were high positively correlated with each other and negative with

temperature. In the study of temperature and air pollutants, we found that these two factors are positive correlation with FEV1/FVC in both single and two pollution model (NO_2) in winter. Our results are consistent with the study conducted by Yi Li in Beijing, they founded that low temperature enhanced the impacts of PM2.5 on cardiovascular mortality[27]. FEV1/FVC is the ratio of forced expiratory volume in the first second to all expiratory volume, which reflects the airway obstruction index and is more sensitive, The synergistic effect of temperature and PM2.5 was founded in winter[28].

There are two major strengths in this study. This is the first article to study the effect of $PM_{2.5}$ and temperature on lung function in healthy people in Northwest China. Second, Other articles usually refer to PEF and FEV1 as indicators of lung function. In this study, five indicators were included which are more comprehensive.

However, the limitations of this study worth noting. First, the population participated in the study are mainly yellow, middle-aged men and women living in Northwest China, which limits the universality of the population. Secondly, measurement of community temperature and pollutants ignores the potential significant differences that may affect individual residential temperature. Third, research period is relatively short, only 30 days are included in each quarter, which is not enough to represent the temperature change of the whole season. Last, our study focuses on two extreme temperature seasons, summer and winter, and ignores the seasons with mild climate conditions in spring and autumn.

Conclusions

In conclusion, our research suggests that exposure to $PM_{2.5}$ in winter has an acute adverse effect on lung function among healthy people in Xi'an of China. Further big number of subjects from different countries needed to be included to confirm these findings.

Abbreviations

GEEs=generalized estimating equations; PM2.5=particulate matter with an aerodynamic diameter<2.5 μm; NO2=nitrogen dioxide; SO2=sulfur dioxide; PEF= peak expiratory flow; FEF25-75= forcedexpiratory flow from 25-75%; FEV1/FVC=; PET= pulmonary function test; COPD= chronic obstructive pulmonary disease; TORCH= towards a revolution in COPD Health; BMI= Body Mass Index.

Declarations

Acknowledgments：No

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due other analyses are proceeding but are available form the corresponding author on reasonable request.

Ethics approval and consent to participate

The study protocol was approved by the Institutional Ethics Committee of the First Affiliated Hospital of Xi'an Medical College (No.XYYFY2017LSK-017).All participants signed the consent form before entering the study.

Author contributions: Y.Y. designed the study, conducted analysis, and drafted the work; J.Z made substantial contribution to design of the work , interpretation of the work, and revising the draft for important intellectual contant; Y.T. made substantial contribution to analysis and interpretation of the work; X.D. revised the draft for important intellectual content; H.C. and J.Z.Z. helped with access to the data, data management, and analysis; S.Y.W made substantial contributions to the conception of the work, revising the draft for important intellectual content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests: None declared.

Patient consent for publication Not required.

Ethics approval: The study was deemed form ethical approval by the institutional review board of the first affiliated hospital of Xi'an medical university (No. **XYYFY2017LSK-017**).

References

1. Bokov P, Delclaux C. Interpretation and use of routine pulmonary function tests: Spirometry, static lung volumes, lung diffusion, arterial blood gas, methacholine challenge test and 6-minute walk test. Rev Med Interne. 2015; 37:100-110.
2. Miller JI, Grossman GD, Hatcher CR. Pulmonary function test criteria for operability and pulmonary resection. Surgery Gynecology & Obstetrics.1982; 153:893-895.
3. Hou G, Wang QY, Kang J. Investigation of the prevalence of pulmonary function test in Liaoning province and the cognition of COPD patients to the test. J Med China.2010; 131:180-192
4. Bobbio A, Chetta A, Carbognani P, et al. Changes in pulmonary function test and cardio-pulmonary exercise capacity in COPD patients after lobar pulmonary resection. Eur J Cardiothorac Surg. 2005; 28:754-758
5. Song G, Mortani Barbosa E, Tustison N, et al. A Comparative Study of HRCT Image Metrics and PFT Values for Characterization of ILD and COPD. Academic Radiology.2018; 19:857-864
6. Jenkins CR, Celli B, Anderson JA, et al. Seasonality and determinants of moderate and severe COPD exacerbations in the TORCH study. Eur Respir J. 2018; 39:38-45

7. Liu J, Li Y, Li J, et al. Association between ambient PM2.5 and children’s hospital admissions for respiratory diseases in Jinan, China. Environ Sci Pollut Res Int. 2019; 26(23):24112-24120.
8. Li S, Xu J, Jiang Z, Luo Y, et al. Correlation between indoor air pollution and adult respiratory health in Zunyi City in Southwest China: situation in two different seasons. BMC public health 2019; 19:723
9. Song WM, Liu Y, Liu JY, et al. The burden of air pollution and weather condition on daily respiratory deaths among older adults in China, Jinan from 2011 to 2017. Medicine. 2019; 98:e14694
10. Mentese S, Bakar C, Mirici NA, et al. Associations between respiratory health and ambient air quality in Canakkale, Turkey: a long-term cohort study. Environ Sci & Pollut Res Int. 2018; 25:1-17
11. Zhang Y, Mingquan H, Simin W, et al. Short-Term Effects of Fine Particulate Matter and Temperature on Lung Function among Healthy College Students in Wuhan, China. Inter J Environ Res Public Health.2015; 12(7):7777-7793
12. Qian Z, He Q, Lin HM, et al. High Temperatures Enhanced Acute Mortality Effects of Ambient Particle Pollution in the “Oven” City of Wuhan, China. Environ Health Perspect.2018;116:1172-1178
13. Hanley, A. J. Statistical Analysis of Correlated Data Using Generalized Estimating Equations: An Orientation. Environ Health Perspect.2018;116:1172-1178
14. Bernard SM, Samet JM, Grambsch A, et al. The potential impacts of climate variability and change on air pollution-related health effects in the United States. Environ Health Perspect.2001; 109:199-209
15. Orru H, Ebi KL, Forsberg B. The Interplay of Climate Change and Air Pollution on Health. Curr Environ Health Rep.2017;4(4):504-513.
16. Yienger JJ, Galanter M, Holloway TA, et al. The episodic nature of air pollution transport from Asia to North America. JGR Atmospheres.2000; 105:26931
17. Curto A, Wellenius GA, Milà C, et al. Ambient Particulate Air Pollution and Blood Pressure in Peri-urban India. Epidemiology (Cambridge, Mass.).2019; 30:492-500
18. Liu K, Wu Q, Wang L, et al. Measure-Specific Effectiveness of Air Pollution Control on China's Atmospheric Mercury Concentration and Deposition during 2013-2017. Environ sci Technol. 2019;53(15):8938-8946.
19. Fan RB, Li HY, Wang WX. Research on Micro-Climate Improvement of Traditional Guanzhong Dwellings — Case Study of Xi’an Sanxuejie Historic District. Applied Mechanics & Materials.2014;584-586:875-880
20. Bei N, Li G, Huang R, et al. Typical synoptic situations and their impacts on the wintertime air pollution in the Guanzhong basin, China. Atmos Chem Phys.2016;1-34
21. Haryanto B, Resosoedarmo B, Utami STB, et al. Effect of Ambient Particulate Matter 2.5 Micrometer (PM2.5) to Prevalence of Impaired Lung Function and Asthma in Tangerang and Makassar. Kesmas Jurnal Kesehatan Masyarakat Nasional. 2016,145-149.
22. Chen. BY, Chen. CH, Chuang. YC, et al. Changes in the relationship between ambient fine particle concentrations and childhood lung function over 5 years. Environ Res. 2019;179(Pt B):108809

doi:10.1016/j.envres.2019.108809.
23. Rice. MB, Li. W, Wilker. EH, et al. Association of outdoor temperature with lung function in a temperate climate. Eur Respir J. 2019; 53: 1800612.
24. Mcmichael A J, Wilkinson P, Kovats R S, et al. International study of temperature, heat and urban mortality: the "ISOTHURM" project. Int J Epidemiol. 2008, 37(5):1121-1131.
25. Wang Q, Suixin L, Yaqing Z, et al. Characteristics of Black Carbon Aerosol during the Chinese Lunar Year and Weekdays in Xi’an, China. Atmosphere.2015; 6:195-208.
26. Han YM, Chen LWA, Huang RJ, et al. Carbonaceous aerosols in megacity Xi\"an, China: Implications of thermal/optical protocols comparison. Atmos Environ.2016; 132:58-68.
27. Li Y, Ma Z, Zheng C, et al. Ambient temperature enhanced acute cardiovascular-respiratory mortality effects of PM2.5in Beijing, China. Int Journal Biometeorol. 2015;59: 1761-1770
28. Quanjer PH, Stanojevic S, Stocks J, et al. Changes in the FEV1/FVC ratio during childhood and adolescence: an intercontinental study. Eur Res J.2010; 36:1391-1399.

Tables

Due to technical limitations, Tables 1-5 are provided in the Supplementary Files section.

Figures

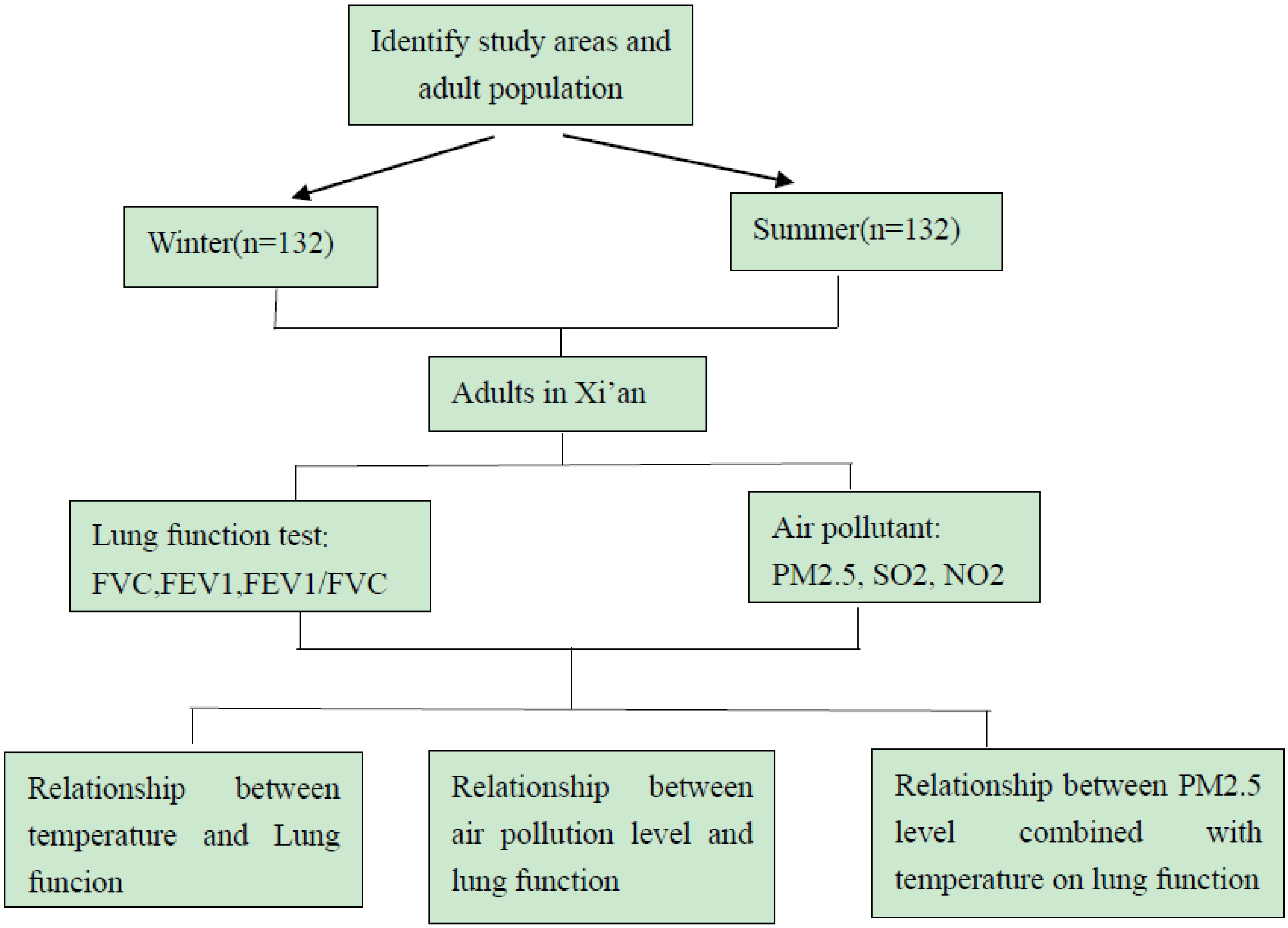

Figure 1

Research flowchart

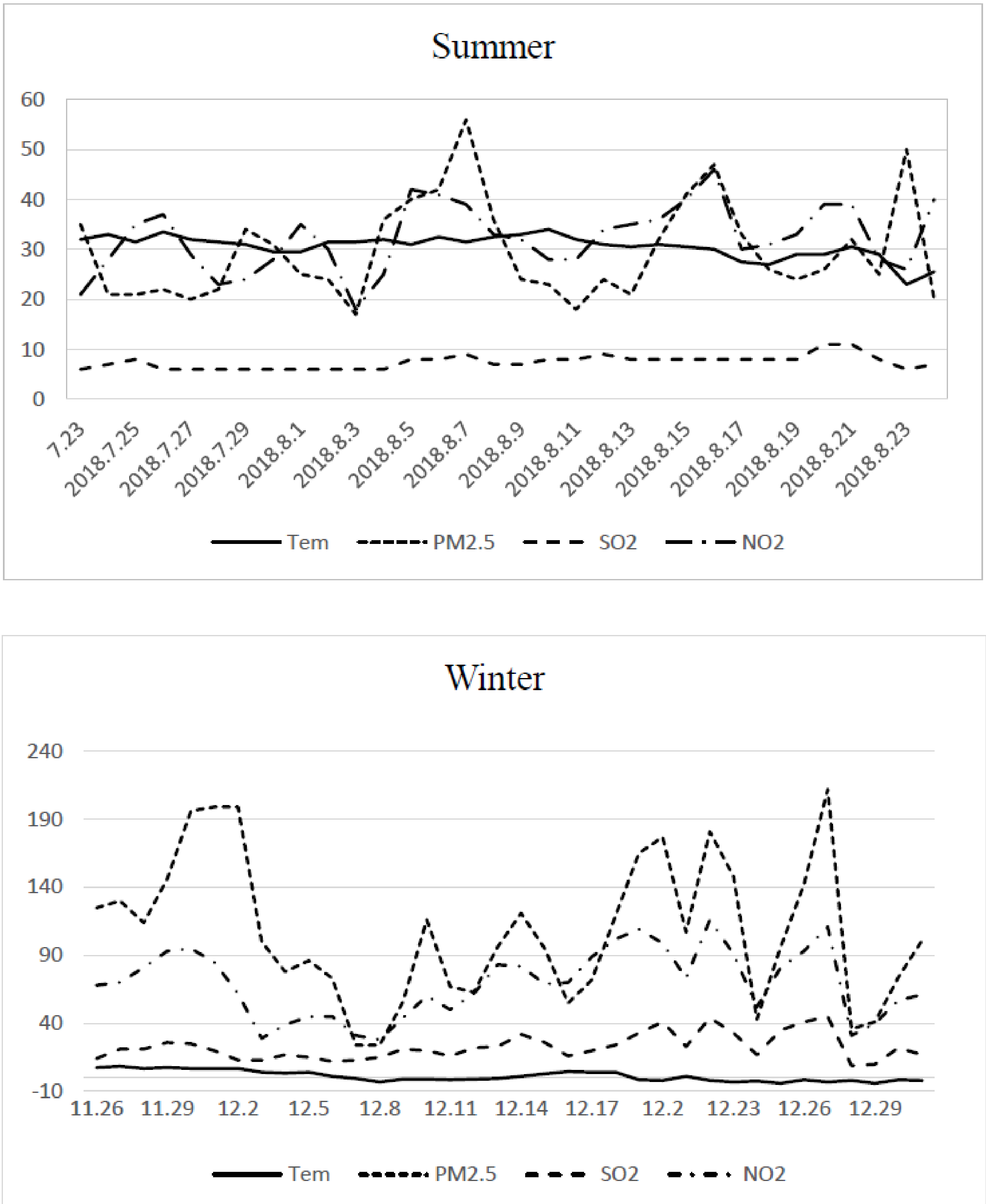

Figure 2

The concentrations of Temperature, PM2.5, SO2 and NO2 for each subject during the study period.

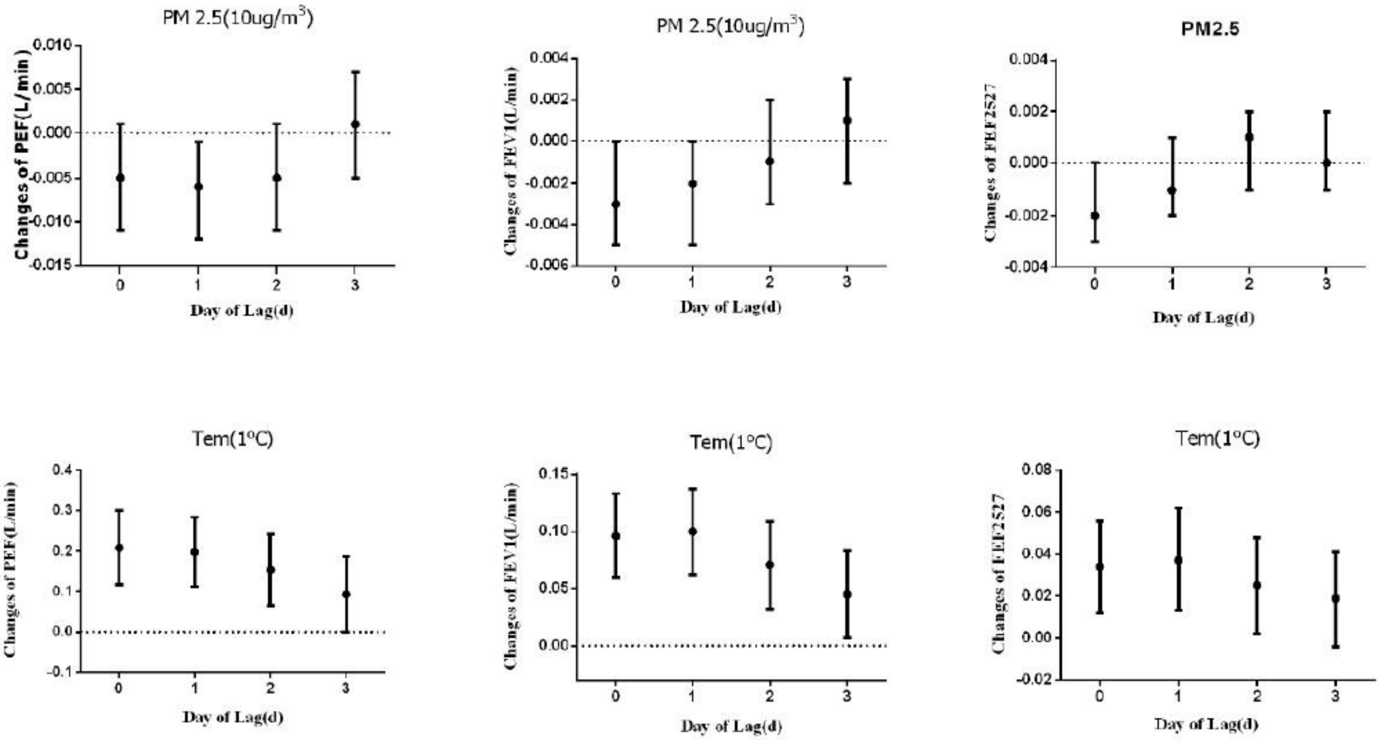

Figure 3

Lagged effects of PM2.5 and Temperature on PEF, FEVA and FEF25-75 in single-pollutant model.

Supplementary Files

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- table.pdf