ACS Partner Journal

ENVIRONMENT & HEALTH

pubs.acs.org/EnvHealth

Article

Impacts of Household Solid Fuel Combustion on Blood Pressure: Mechanisms and Implications

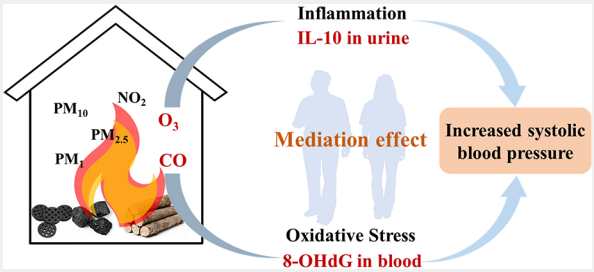
Meixuan Liu, Hongmei Xu,* Yunxuan Gu, Jianhong Zhu, Hongai Zhang, Hongwei Lu, Jian Sun, Zhenxing Shen, and Junji Cao

Cite This: *Environ. Health* 2025, 3, 458−468

Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information

ABSTRACT: Rural households in northwest China rely on solid fuels as their main heating energy source in winter, leading to negative health outcomes. This study assessed the concentrations of personal exposure to size-resolved particulate matter and gaseous pollutants (NO_2, CO, and O_3) and their effects on biomarkers of inflammation and oxidative stress in 129 rural residents who use solid fuels in the Fenwei Plain in winter. The results showed that NO_2 exposure significantly increased IL-6 and TNF-α in urine (u), O_3 exposure significantly increased 8-OHdG and IL-10 in urine (u), and CO exposure caused significantly increased 8-OHdG in blood (b). Four urine biomarkers positively correlated with systolic blood pressure (SBP); 8-OHdG-b was significantly positively correlated with both SBP and diastolic blood pressure (DBP). Mediation analysis showed that O_3 and CO mediated the association between IL-10-u and SBP and 8-OHdG-b with SBP. O_3 and CO exposure caused by domestic solid fuel combustion may lead to an increase in human SBP by mediating systemic inflammation and oxidative stress. The study emphasizes the urgency of improving rural household heating methods and reducing air pollution to alleviate the burden of diseases associated with hypertension and provides a scientific basis for understanding the pathogenesis and early prevention of hypertension among rural residents in northwest China.



KEYWORDS: *solid fuel combustion, personal exposure, biomarker, blood pressure, mediating effect*

1. INTRODUCTION

In rural areas of northwest China, solid fuels (such as tree branches, crop stalks, and coal) are still the main heating energy sources for local households in winter.[1] In these areas, residents use traditional stoves to burn fuels, resulting in imperfect combustion.[2,3] Due to a lack of ventilation equipment, a large number of air pollutants, such as particulate matter (PM), carbon monoxide (CO), and nitrogen dioxide (NO_2),[4−9] remain indoors, leading to the deterioration of indoor air quality.

Oxidative stress, is a physiological state in which there is an overproduction of reactive oxygen species (ROS), and an imbalance between them and antioxidants, resulting in imbalance in cellular damage, producing pro-inflammatory mediators and systemic inflammation.[10,11] Exposure to atmospheric pollutants emitted from solid fuel combustion can induce oxidative stress.[12] All these processes may cause acute and chronic diseases, such as chronic obstructive pulmonary disease, lung cancer, stroke, ischemic heart disease, and hypertension.[13−15] Using biomass fuels increases the risk of pneumonia by more than 80% compared to using cleaner fuels.[16] Inhaling PM from solid fuel combustion is thought to cause the rapid release of endothelin and a significant increase in plasma viscosity and induce the production of C-reactive protein in the liver, which leads to vascular endothelial stiffness and the development of hypertension.[5,17,18] Gaseous CO and NO_2 released during the combustion of solid fuels increase the risk of respiratory infections and cardiovascular damage and CO can also cause acute death through tissue oxygenation.[19,20]

Hypertension is one of the most common diseases among middle-aged and elderly people in China.[21] According to the blood pressure report released by the World Health Organization (WHO), the number of adults aged 30−79 with hypertension in China in 2019 was about 257 million.[22] The annual deaths related to hypertension account for nearly 80% of cardiovascular disease deaths in China.[23,24] Both innate and adaptive immunity could promote elevated blood pressure by triggering vascular inflammation and microvascular remodeling.[25] Higher concentrations of inflammatory factors (e.g., interferon-gamma (IFN-γ), interleukin-17 (IL-17), and tumor necrosis factor-alpha (TNF-α)) in the blood have been associated with a higher risk of developing hypertension.[26,27] 8-hydroxydeoxyguanosine (8-OHdG) in blood and urine has

Received: September 19, 2024
Revised: December 23, 2024
Accepted: December 25, 2024
Published: January 22, 2025

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

also been shown to be associated with cardiovascular diseases such as hypertension.[28] Several surveys of adults over the age of 18 found that an increase in the count of white blood cells indicating inflammation was associated with an increase in blood pressure.[29,30] Studies have indicated that inflammation and oxidative stress show a possible mediating role in polycyclic aromatic hydrocarbons (PAHs)-induced liver impairment.[31] However. whether this also has a mediating effect on hypertension, especially for rural residents exposed to solid fuel combustion, is unknown.

The Fenwei Plain in northern China was one of the three key areas designated for air pollution control by China's Ministry of Environmental Protection in 2018. Nonclean solid fuels, such as coal and biomass, are the main energy sources in the heating season in the rural areas of the Fenwei Plain and are the main pollution sources that lead to the deterioration of the local atmospheric environment in winter.[32,33] Therefore, this study used wearable real-time sensors to collect the concentration of air pollutants in different microenvironments of subjects, representing personal exposure concentration, and determined the personal exposure concentrations of multiple air pollutants in the solid fuel-using population.[34,35] This study also qualitatively assessed the effects of air pollutants on biomarkers of inflammation and oxidative stress biomarkers in blood and urine, and investigated the mediating roles of inflammatory factors and oxidative stress in the association between respiratory exposure to air pollutants and blood pressure in the rural population of the Fenwei Plain, and to further revealed the health implications of solid fuel. The results will provide a theoretical basis for the early intervention of hypertension in rural residents of Northwest China and a new perspective for understanding the possible mechanism of the incidence rate of hypertension in local rural residents.

2. MATERIALS AND METHODS

2.1. Study Design

Shibao village (109.33°E, 35.44°N) in Tongchuan city is located in the central part of Shaanxi Province and the northernmost of the Guanzhong Plain. It is at a high altitude (1395 m) and has a low temperature in winter (4.46 ± 3.56 °C). There is almost no industry or commerce. Due to the large production of coal,[36] as well as the cheap and easy availability of biomass fuels in Tongchuan, the residents of Shibao village (about 1000 households) commonly use these two solid fuels in winter for heating at home. The compositional analysis of the local coal is detailed in Table S2 in the Supporting Information (SI). There are almost no households in the area using clean energy (such as natural gas, electricity) for winter heating. A total of 141 participants (all over 45 years old) were recruited between December 2022 and January 2023 (the selection process and criteria for participants are in Appendix A of the Supporting Information (SI)). During this period, basic physical examinations (measuring height, weight, blood pressure, etc.), real-time concentrations of personal exposure to air pollutants, and blood and urine sample collections were conducted for each participant (Figure S1). The study was approved by the Biomedical Ethics Committee of the Xi'an Jiaotong University Health Science Center in China (registration number: 2018−532) and all participants provided written informed consent.

2.2. Questionnaire Survey

Trained researchers conducted a questionnaire survey with all the participants individually. The participants were asked to fast in the morning. The questionnaire included basic personal information (gender, age, education, income, family members, etc.), health status (self-assessment of health during the sampling period, past medical history, medication history, etc.), living environment (house size, pets, plants, etc.), and living habits (smoking, secondhand smoke, alcohol consumption, type of heating or cooking fuel used, ventilation habits, exercise frequency, etc.). Surveys of diet (including frequency of eating high salt pickled food) were also conducted. Based on the questionnaire results, 12 of the 141 participants were excluded from the formal experiment as they were taking antihypertensive medications. Therefore, all data analyses were based on 129 valid participants.

2.3. Blood and Urine Sample Collection

After the questionnaire survey, avoiding strenuous exercise for half an hour before the physical examination was required. First, the heights and weights of each participant were measured. Systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate were measured using an electronic sphygmomanometer (Omron J732, Japan), followed by venous blood collection. After the measurement, each subject was given a sealed and sterilized urine tube (10 mL; Yunya, Nantong, China) to collect morning urine in the middle of the following day. In total, 129 eligible blood and urine samples were obtained. Urine and blood samples were centrifuged, dispensed, and otherwise pretreated and transferred to a laboratory refrigerator at 4 °C within 4 h and to a refrigerator at −80 °C within 3 days for subsequent analysis, using bioice packs to maintain cold temperature during transportation.

2.4. Personal Exposure to Air Pollutants Data Collection

The SAPIENS Air Quality Sensor (Shenzhen Environmental Technology Co., Ltd., Shenzhen, Guangdong, China) was used to collect real-time individual exposure concentration data for six types of atmospheric pollutants (PM_{10}, $PM_{2.5}$, PM_1, NO_2, CO, and O_3) for each participant over a 24 h period with a resolution of 1 min immediately after the physical examination. This study used the arithmetic average of 24 h of online data to represent individual exposure concentrations. During nonsleep hours, each participant wore an air quality sensor on the chest (within 0.3 m of nose and mouth), and during sleep, he/she placed the sensor near the head in the bedroom (within 0.5 m of nose and mouth). The performance of the sensors is detailed in the Appendix D of the Supporting Information.

2.5. Measurement of the Biomarkers

Based on the pre-experimental results, urine and blood samples were thawed at room temperature and centrifuged at 1000 rpm for 10 min. The supernatant was extracted for analysis of four urine biomarkers (suffix u for urine): IL-6-u, IL-10-u, TNF-α-u, and 8-OHdG-u, and four blood biomarkers (suffix b for blood): IL-10-b, 8-OHdG-b, lymphocyte count (LYMP) and monocyte count (MONO). IL-6, IL-10, and TNF-α are factors produced by immune cells and involved in inflammation and immune response, among which IL-6 and TNF-α are pro-inflammatory factors and IL-10 is an anti-inflammatory factor.[37−39] 8-OHdG is a specific biomarker of oxidative stress and DNA damage.[40] Monocyte and lymphocyte are immune cells, which are produced in the bone marrow and lymphatic organs of the human body, respectively.[41,42] And it has been shown that these two types of immune cells may be associated with the development of hypertension.[43] Detailed methods for analyzing the biomarkers can be found in the Appendix B of the Supporting Information.

2.6. Statistical Analysis

2.6.1. Data Processing. Excel 2019 (Microsoft Corporation, Redmond, WA, USA) was used for data entry, SPSS 26.0 (International Business Machines Corporation, Armonk, New York, USA) was used for statistical analysis, and Origin 2022 (Origin Lab, Northampton, MA, USA) was used for statistical analysis and plotting. Tests of Spearman's linear correlation, multiple linear regression analyses were used to determine associations between air pollutant concentrations, biomarkers, and blood pressure. The effects of air pollutants in different concentration intervals on biomarkers were further explored using three-category ordinal regression analysis,

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

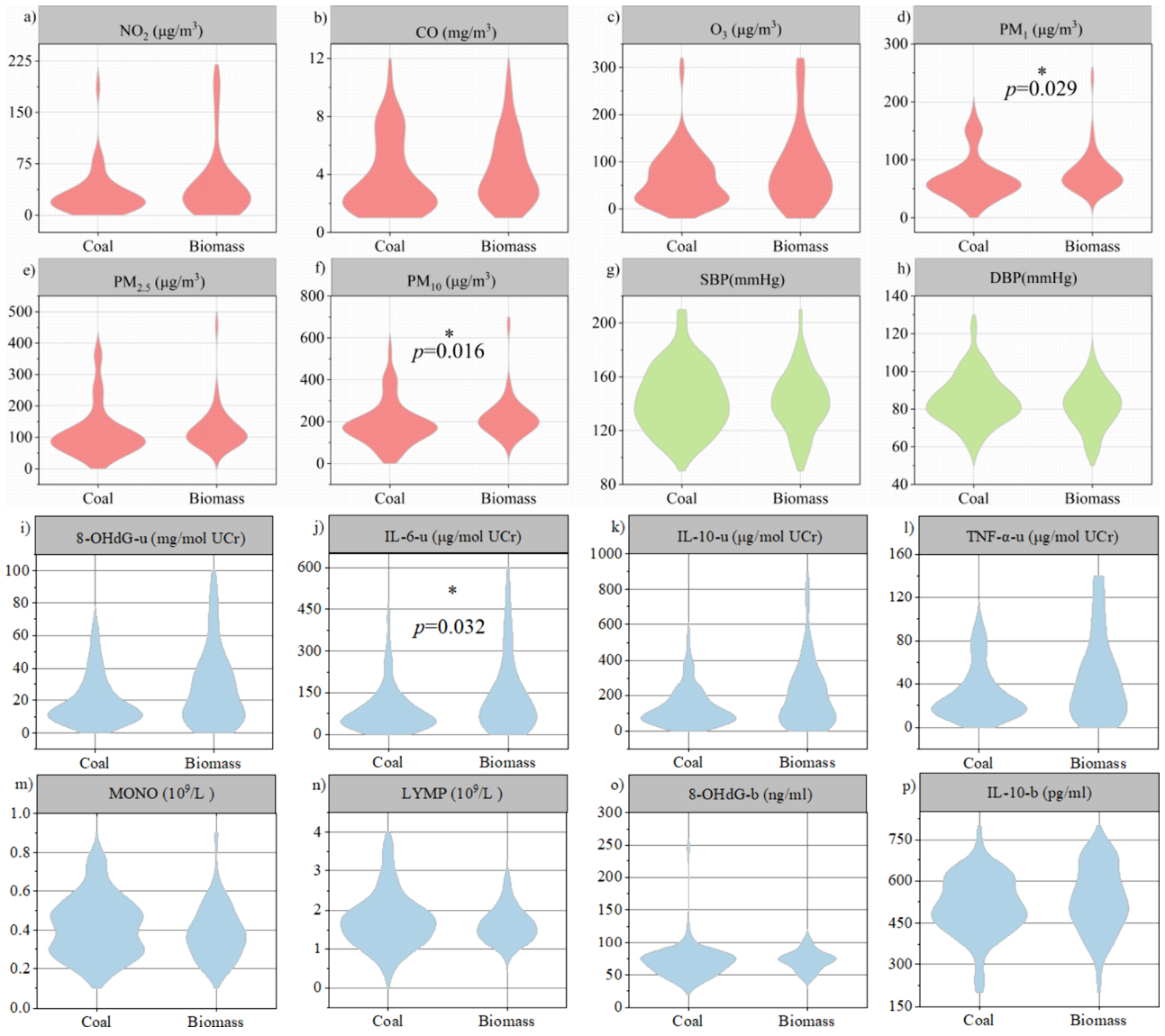


Figure 1. Comparisons of personal exposure to air pollutant concentrations (Figure a-f), blood pressure (Figure g-h), and biomarker concentrations (Figure i-p) in different fuel groups.

which is described in more details in the Appendix C of the Supporting Information.

2.6.2. Mediation Analysis. To explore the potential mediating role of blood and urine biomarkers between respiratory exposure to air pollutants and blood pressure, a mediation analysis was conducted using the process plug-in in SPSS created by Hayes in 2013.[44] Biomarkers were used as mediators, air pollutants as independent variables, and blood pressure as the dependent variable to estimate total, direct, and indirect effects. The indirect effect is the effect of the independent variable transmitted through one or more mediating variables. The process plug-in used the bootstrap method to test and judge the mediation effect according to whether the confidence interval contained 0. A mediation effect is present if the 95% confidence interval for the output indirect effect does not contain the number 0, which is significant for the indirect effect.[45−47]

3. RESULTS AND DISCUSSION

3.1. Personal Information and Hypertension Incidence Rate of Participants

According to the questionnaire, the residents of this region spend more than 85% (20.5 ± 2.89 h) of their time indoors in winter and there is an obvious combustion source indoors. Therefore, we categorized the population according to the type of fuels used in the participants' households: coal group (80 participants) and biomass group (49 participants). Statistical analysis of the basic information on the 129 valid participants in this study is shown in Table S1. Of the participants, 85 were female and 44 were male and the age range was 40−88 years old, with an average value of 62.7 ± 11.8. The average BMI was 23.0 ± 4.76 kg/m^2. Of the participants, 38.3% had an elementary school education or lower, 43.8% had a middle school education, and 17.9% had a high school education. Three days before sampling, 9.3% of the participants had respiratory symptoms, such as colds and coughs, and 30.2% used medications other than antihypertensive drugs. Only 23.3% of the participants were smokers; however, 41.9% were exposed to secondhand smoke. Only 10.1% were alcohol drinkers. In addition, 68.9% of the participants rarely exercised. More than 90% of the participants used closed or semiclosed kitchens and only 20.9% used ventilation during cooking,

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

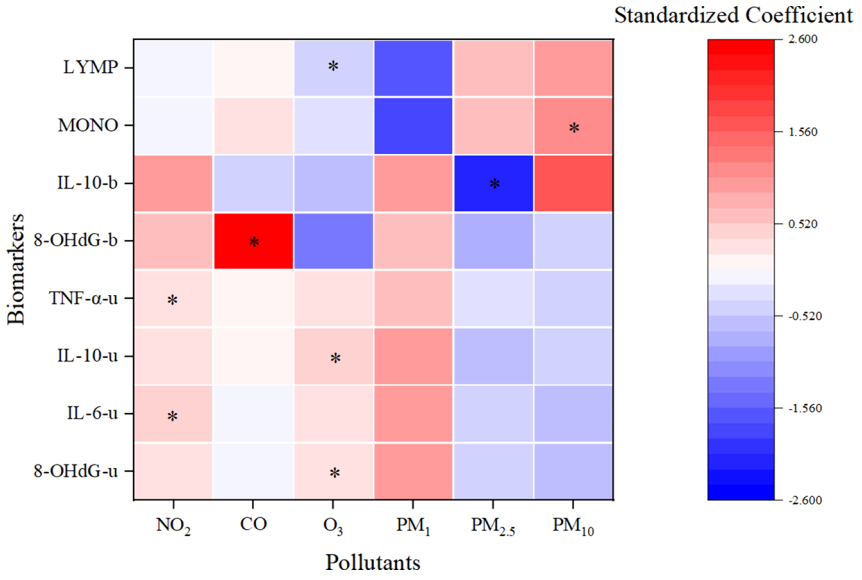


Figure 2. Correlation of biomarkers with personal exposure to air pollutants.

indicating that most of the residents' indoor air pollutants could not be exhausted to the outside in a timely manner.[48,49]

According to the recommendations of the WHO/International Society of Hypertension in 2003,[50] hypertension is diagnosed when SBP rises to ≥140 mmHg or DBP rises to ≥90 mmHg and prehypertension is diagnosed when SBP rises to 120−139 mmHg and DBP rises to 80−89 mmHg. Among the valid participants, the prevalence of hypertension was 55%, less than 20% of the participants had normal blood pressure, and the remaining participants had prehypertension. The prevalence of hypertension in Chinese urban adults ranges from 28.9% to 48.6%,[51−53] with a prevalence of 43.1% in the elderly in previous studies,[54] lower than that in the present study. These results suggest that the prevalence of hypertension is high among middle-aged and elderly residents in rural areas of northwest China. The living habits, such as using solid fuels for heating, staying indoors for long periods and lack of indoor air ventilation may be potential factors contributing to hypertension for rural residents, which need to be further explored.

3.2. Personal Exposure to Air Pollutants and Biomarkers in Different Fuel Groups

During the sampling period, the concentrations of six air pollutants exposed to different fuels are shown in Figure 1a-f. The concentrations of NO_2, CO, O_3, PM_1, $PM_{2.5}$, and PM_{10} were 36.5 ± 41.0 $\mu g/m^3$, 3.95 ± 2.43 mg/m^3, 71.1 ± 66.8 $\mu g/m^3$, 71.9 ± 36.9 $\mu g/m^3$, 119 ± 74.5 $\mu g/m^3$, and 202 ± 100 $\mu g/m^3$, respectively. Due to the lack of standards for human exposure to air pollutants, the results of this study were compared with those in the Chinese indoor air quality standards (GB/T 18883−2022).[55] The exposure concentrations of $PM_{2.5}$ and PM_{10} were 2.4 and 2.0 times the standard values ($PM_{2.5} \leq 50$ $\mu g/m^3$ and $PM_{10} \leq 100$ $\mu g/m^3$) and the concentration of the rest of the gaseous pollutants were much lower than the standard values ($NO_2 \leq 200$ $\mu g/m^3$, CO ≤ 10 mg/m^3, and $O_3 \leq 160$ $\mu g/m^3$), which suggests that exposure to PM pollution is more severe among rural residents using solid fuels. This implies the need to upgrade the concentration threshold standards for gaseous pollutants in China. Among all the air pollutants, the exposure concentrations of the biomass group were higher than that of the coal group, significantly for PM_1 (coal: 68.3 ± 37.8 $\mu g/m^3$, biomass: 77.4 ± 35.1 $\mu g/m^3$, p = 0.029) and PM_{10} (coal: 190 ± 103 $\mu g/m^3$, biomass: 219 ± 93.9 $\mu g/m^3$, p = 0.016).

The SBP and DBP values of the different fuel groups are shown in Figure 1g-h. The SBP (144 ± 24.4 mmHg) and DBP (85.3 ± 13.5 mmHg) of the coal group were higher than those of the biomass group (SBP: 142 ± 22.1 mmHg and DBP: 81.7 ± 11.8 mmHg) but the difference was not significant. The concentrations of the biomarkers in the blood and urine of the different fuel groups are shown in Figure 1i-p and Tables S3−S5. The mean concentrations of 8-OHdG-u, IL-6-u, IL-10-u, and TNF-α-u in the urine samples of 129 validated participants were 22.5 ± 18.9 mg/mol Ucr and 105 ± 104, 159 ± 143, 36.5 ± 31.0 μg/mol Ucr, respectively. The urinary bioindicator concentrations in the biomass group were approximately 1.5 times greater than those in the coal group. Among them, IL-6-u in the biomass group (137 ± 131 μg/mol Ucr) was significantly (p = 0.032) higher than that in the coal group (86.9 ± 78.5 μg/mol Ucr). In blood samples, the mean concentrations of MONO, LYMP, 8-OHdG-b, and IL-10-b were (0.406 ± 0.148) × 10^9/L, (1.69 ± 0.613) × 10^9/L, 71.3 ± 22.5 μg/L, and 520 ± 111 ng/L. 8-OHdG-b, respectively, and IL-10-b maintained the same pattern as the urine indicators; that is, the biomass group had higher values than the coal group but the difference was not significant. MONO and LYMP in the coal group ((0.418 ± 0.513) × 10^9/L and (1.74 ± 0.699) × 10^9/L) were slightly higher than those in the biomass group ((0.388 ± 0.139) × 10^9/L and (1.62 ± 0.439) × 10^9/L), but the difference was not significant.

Although there were significant differences in personal exposure concentrations in the biomass and coal groups for PM_1 and PM_{10}, there were no significant differences in blood pressure and biomarkers between the two groups. This may be due to the fact that, biomass and coal are traditional solid fuels, with limited differences in the fuel self-and the types of air pollutants emitted from combustion[56] In addition, the study population involved in this study have basic closer lifestyle habits (Table S1), which resulted in more similar health levels of system inflammation and oxidative stress in different groups of residents. Therefore, to obtain better statistical analysis

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

performance and generalizable findings, all valid participants (129) from both two solid fuel groups were analyzed as a whole in the subsequent study.

3.3. Linkage between Exposure to Air Pollutants and Biomarkers

3.3.1. Correlation between Biomarkers and Air Pollutants. *Gaseous Pollutant.* Exposure to air pollutants leads to an increase in the concentration of pro-inflammatory mediators and reactive oxygen species (ROS) in the body, which in turn induces a variety of diseases.[57] Several epidemiologic studies have shown that indoor air pollutants can lead to elevated concentrations of 8-OHdG, ILs, and TNF-α in humans.[58,59] In cellular experiments, the concentrations of TNF-α and IL-6 secreted by cells increased with increasing concentrations of exposed air pollutants.[60] The correlation of eight biomarkers in the participants' blood and urine samples and six exposed air pollutants (Table S6) showed that only CO was significantly positively correlated with 8-OHdG-b (p = 0.033) and O_3 was significantly positively correlated with 8-OHdG-u (p = 0.047), IL-6-u (p = 0.049), and IL-10-u (p = 0.023). When confounders, such as gender, age, BMI, smoking, and alcohol consumption, were excluded, the correlations between air pollutants and biomarkers were as shown in Figure 2. NO_2 was significantly positively correlated with IL-6-u (p = 0.024) and TNF-α-u (p = 0.035). NO_2 is an environmental oxidant and its mediated lung injury is associated with higher concentrations of pro-inflammatory mediators and cytokine production.[61] Studies conducted in humans or cells have shown that exposure to NO_2 can cause a significant increase in the cellular pro-inflammatory factors IL-1β, TNF-α, and IL-6, as well as correlating with a decrease in LYMP in humans,[61−63] which is consistent with the findings in the current study. Moreover, CO was significantly and positively correlated with 8-OHdG-b (p = 0.018), possibly because CO inhibits mitochondrial respiration, leading to increased levels of ROS, which in turn induce oxidative stress.[64]

O_3 was positively correlated with 8-OHdG-u (p = 0.049) and IL-10-u (p = 0.021) and negatively correlated with LYMP (p = 0.043). O_3 is a strong oxidant that enters the body and prompts oxidative reactions in the organism, leading to subcellular damage; and repeated exposure to low doses of O_3 causes an imbalance in the antioxidant mechanism, leading to oxidative stress in the organism.[65−67] In the present study, O_3 had a significant promoting effect on the concentrations of IL-10 and 8-OHdG in urine samples but a nonsignificant and opposite effect on IL-10 and 8-OHdG in blood. This indicates that the processes of oxidative stress and inflammatory response to O_3 in the human body occur in different human metabolic pathways and these two biomarkers in urine are more suitable as health risk indicators for O_3 exposure than blood in the case of solid fuel combustion. In addition, inhalation of O_3 adversely affects the T lymphocyte immune system and induces a neuroendocrine stress response, both of which can result in reduced MONO and LYMP levels in the blood.[68,69]

Particulate Matter. There was a significant positive correlation between blood TNF-α, IL-8, IL-6, and IL-10 and indoor PM concentrations in populations using solid fuels.[70,71] However, based on the results of Figure 2 and Table 1, PM were almost not strongly correlated with biomarkers, except for PM_{10}, which was positively correlated with MONO (p = 0.049) and $PM_{2.5}$, which was negatively correlated with IL-10-b (p = 0.042). Studies have reported that exposure to PM_{10} stimulates macrophages, which can accelerate the release of monocytes from the bone marrow.[72] The weak correlations in this study may be due to the different chemical compositions of PM.[73] It has been shown that different fractions of $PM_{2.5}$ (water-soluble, fat-soluble and insoluble components) contribute to elevated concentrations of different types of

Table 1. Three-Category Ordinal Regression of Exposure to Air Pollutants on Biomarkers

		OR (LI)	OR (MI)
NO_2	8-OHdG-u	0.88	1.37
	IL-6-u	1.10	0.98
	IL-10-u	1.10	1.22
	TNF-α-u	1	1.12
	MONO	1.27	3.35[a]
	LYMP	0.33	1.46
	8-OHdG-b	0.60	0.79
	IL-10-b	0.49	0.90
O_3	8-OHdG-u	3.32[a]	1.62
	IL-6-u	1.71	1.42
	IL-10-u	3.22*	1.39
	TNF-α-u	1.68	1.73
	MONO	0.27[a]	0.28[a]
	LYMP	1.09	0.69
	8-OHdG-b	0.83	0.75
	IL-10-b	1.72	1.30
CO	8-OHdG-u	1.00	1.00
	IL-6-u	0.86	1.32
	IL-10-u	0.62	0.85
	TNF-α-u	0.74	0.79
	MONO	0.69	0.98
	LYMP	0.86	2.20
	8-OHdG-b	3.34[a]	3.27[a]
	IL-10-b	0.70	1.32
PM_1	8-OHdG-u	1.14	1.33
	IL-6-u	1.60	1.43
	IL-10-u	1.05	1.53
	TNF-α-u	1.07	1.65
	MONO	0.54	0.62
	LYMP	0.63	0.50
	8-OHdG-b	2.10	1.42
	IL-10-b	1.45	0.53
$PM_{2.5}$	8-OHdG-u	1.07	1.16
	IL-6-u	1.46	1.55
	IL-10-u	0.99	1.35
	TNF-α-u	1.00	1.48
	MONO	0.42	0.76
	LYMP	0.63	0.63
	8-OHdG-b	1.59	1.10
	IL-10-b	1.07	0.57
PM_{10}	8-OHdG-u	1.25	1.23
	IL-6-u	1.49	1.52
	IL-10-u	0.98	1.34
	TNF-α-u	1.09	1.33
	MONO	0.51	0.69
	LYMP	0.51	0.80
	8-OHdG-b	2.38	1.25
	IL-10-b	1.25	0.94

[a]p < 0.05, OR (LI): OR of biomarkers for low-concentration interval (LI) exposure, OR (MI): OR of biomarkers for medium-concentration interval (MI) exposure.

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

Table 2. Correlation of Biomarkers with Blood Pressure

		8-OHdG-u (μg/mol Ucr)	IL-6-u (μg/mol Ucr)	IL-10-u (μg/mol Ucr)	TNF-α-u (μg/mol Ucr)	8-OHdG-b (ng/mL)	IL-10-b (pg/mL)	MONO (10^9/L)	LYMP (10^9/L)
SBP	*P* value	0.002[a]	0.004[a]	0.003[a]	0.004[a]	0.018[a]	0.902	0.135	0.127
	Correlations	0.292	0.268	0.277	0.267	0.215	−0.011	0.154	0.180
DBP	*P* value	0.425	0.208	0.307	0.321	0.037[a]	0.157	0.326	0.070
	Correlations	−0.075	−0.118	−0.096	−0.093	0.189	0.126	0.093	0.171

[a]$p < 0.05$.

Table 3. Mediation Effects of Biomarkers on the Association of Exposure to Air Pollutants with Blood Pressure

X Variable	Y Variable	Mediator	Total effects β (95% CIs)	Direct effects β (95% CIs)	Indirect effects β (95% CIs)
O_3	SBP	IL-10-u	0.0135 (−0.0259, 0.0530)	0.0003 (−0.0387, 0.0393)	0.0132 (0.0007, 0.309)[a]
		8-OHdG-u	0.0135 (−0.0259, 0.0530)	0.0035 (−0.0356, 0.0425)	0.0101 (−0.0002, 0.0247)
NO_2	SBP	IL-6-u	−0.0211 (−0.0680, 0.0258)	−0.0333 (−0.0798, 0.0133)	0.0122 (0.000, 0.0323)
		TNF-α-u	−0.0211 (−0.0680, 0.0258)	−0.0292 (−0.0765, 0.0181)	0.0081 (−0.0017, 0.0237)
CO	SBP	8-OHdG-b	0.0180 (−0.0443, 0.0803)	0.0014 (−0.0630, 0.0659)	0.0165 (0.0003, 0.0421)[a]
	DBP	8-OHdG-b	0.0660 (−0.0489, 0.0621)	−0.0042 (−0.0622, 0.0537)	0.0109 (−0.0064, 0.0301)

[a]Existence of mediation effect.

inflammatory factors.[74] The same inflammatory factor in the body may also be up or down regulated by the different $PM_{2.5}$ chemical components, e.g., metals and ions.[75] In addition, the ground is usually unpaved in rural areas, both indoors and outdoors. The resuspension of ground dust can lead to increased concentration levels of personal exposure to PMs. We know that the dust source PMs has a much lower toxicity than the combustion source PMs.[76] This may also be an explanation for the lack of a significant positive correlation between PMs and health indicators in this study.

3.3.2. Effects of Pollutants in Different Concentration Intervals on Biomarkers. All of these results suggest that air pollutants emitted from solid fuel combustion are indeed associated with inflammation and oxidative stress in humans. To investigate the effects of different concentration intervals of air pollutant exposure on the biomarkers, we conducted a three-category ordinal regression analysis (Table 1). The OR values of 8-OHdG-u in the LI and MI exposure intervals of O_3 were 3.32 ($p = 0.028$) and 1.62, respectively. The OR for IL-10-u in the LI and MI of O_3 were 3.22 ($p = 0.032$) and 1.39, respectively. 8-OHdG-b showed an OR of 3.34 ($p = 0.018$) in the LI and 3.27 ($p = 0.018$) in the MI group of CO, implying that low concentrations of O_3 and medium and low concentrations of CO exhibited significant effects on human inflammation and oxidative stress. In addition, for MONO, the OR in the MI for NO_2 was 3.35 ($p = 0.041$) and in the LI and MI intervals for O_3 were 0.27 and 0.28, respectively, with p-values of both less than 0.05. This suggests that intermediate concentrations of NO_2 and medium and low concentrations of O_3 significantly affect the concentration of MONO in the blood.

3.4. Linkage between Blood Pressure and Biomarkers

The correlations of the eight biomarkers in the blood and urine samples with SBP and DBP are shown in Table 2. All four urine biomarkers were significantly positively correlated with SBP, and 8-OHdG-b was significantly positively correlated with both SBP and DBP. Blood cell count did not show a strong correlation with blood pressure. Epidemiologic studies have displayed that external stimuli lead to the activation of inflammatory vesicles, which induce pro-inflammatory factors within innate immune cells and enhance peripheral organ inflammation, further exacerbating hypertension.[77] In healthy populations, inflammatory cytokines can lead to elevated blood pressure levels through the activation of a variety of neurohumoral and vascular endothelial factors,[78−80] and several studies have demonstrated a significant positive correlation between in vivo concentrations of TNF-α, IL-6, IL-10, and SBP.[78−80] Increased concentrations of 8-OHdG in the body are usually regarded as an increase in the level of systemic oxidative DNA damage. A study on the effects of DNA damage on cardiovascular disease suggested that the mean concentration of 8-OHdG was significantly higher in hypertensive subjects (17.4 ng/mg Ucr) than in normotensive subjects (10.1 ng/mg Ucr, $p < 0.05$).[81] The above results demonstrated that inflammation and oxidative stress are closely related to blood pressure, suggesting that body inflammation and oxidative stress are key processes that induce the development of cardiovascular disease.

3.5. Mediating Effects and Health Implications

We explored the biological link between human respiratory exposure to air pollutants and blood pressure. Mediation analyses were used to explore the potential mechanisms by which exposure to air pollutants affected blood pressure levels through mediators (inflammatory factors and oxidative stress markers). Spearman's correlation analysis showed that no single air pollutant was independently associated with SBP or DBP (Table S7); however, the results of the three-category ordinal regression showed that moderate concentrations of CO had a significant effect on SBP (Table S8). Therefore, we selected biomarkers that were significantly associated with both CO and blood pressure as mediating variables (i.e., 8-OHdG-b). Based on the results in Figure 2 and Table 2, we found that O_3, NO_2, and SBP may be mediated by biomarkers in urine. Therefore, we conducted a mediation analysis of the components that may have functional relationships (Table 3). The results showed that the 95% confidence intervals for the output indirect effects of IL-10-u-mediating effects of O_3 with SBP and 8-OHdG-*b*-mediating effects of CO with SBP did not contain 0, which suggests the presence of significant indirect effects, and hence the presence of mediating effects.[47] Namely, O_3 mediated the association between IL-10-u and SBP, and CO mediated the relationship between 8-OHdG-b and SBP. This suggests a possible mechanism and pathway for the upregulation of SBP in vivo via IL-10 and 8-OHdG,

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

following respiratory exposure to O_3 and CO related to solid fuel combustion emissions in households. This reveals a possible important role of household solid fuel burning air pollutants with biomarkers of inflammation and oxidative stress in the development of hypertension.

Exposure to O_3 and CO induces systemic inflammation and oxidative stress and long-term exposure is associated with an increased incidence of hypertension and cardiovascular disease mortality.[82,83] However, the mechanism is not clear. A study on exposure to gaseous air pollutants and hospitalizations for hypertension found a significant correlation between the number of hospitalizations for hypertension and O_3 concentration,[84] suggesting that O_3 is a major risk factor for hypertension. When O_3 is inhaled, it promotes ROS production. When the ROS produced cannot be cleared by the antioxidant defense mechanism, they are distributed throughout the body, causing oxidative stress and promoting the production of proinflammatory cytokines.[85]

Although previous studies have shown that pro-inflammatory cytokines released by activated T cells contribute to the development of high blood pressure, the anti-inflammatory cytokine IL-10 helps to relieve high blood pressure.[86] However, there is a compensatory interaction between IL-10 and endogenous NO during long-term high salt intake. During prolonged high salt intake, IL-10 can act as a pro-inflammatory cytokine, leading to an inflammatory response. The production of IL-10 can inhibit the formation of endogenous NO, and NO has an inhibitory effect on the incidence of hypertension promoted by angiotensin (AngII).[87] 53% of the participants in this study indicated that they ate high salt pickled food more than 4 days a week based on the diet habits questionnaire survey. Therefore, in this study, IL-10 acted as an intermediary to mediate the relationship between O_3 and hypertension, possibly due to the high salt intake of local rural residents. In a study of salt intake among Chinese residents, Shaanxi Province ranked second among all provinces in China, with a per capita salt intake of 11.7 g/day, which was 2.6 g higher than the average.[88,89] The combustion process of household solid fuels emits large amounts of nitrogen oxides (NO_x) and volatile organic compounds, as well as a lot of free radicals, of which hydroxyl radicals can be used as oxidizers to promote the reaction of NOx and volatile organic compounds to generate high concentrations of O_3.[27,90,91] This causes IL-10, as a pro-inflammatory factor in the body, to increase, inhibiting the production of NO and thus promoting the onset of hypertension. This study concluded that urinary IL-10 can be used as a potential noninvasive bioindicator for determining the cause of hypertension, especially elevated SBP.

When CO is inhaled, it combines with hemoglobin to form hemoglobin carbonate (HbCO), leading to tissue hypoxia.[92] Central nervous system reoxygenation injury can occur after hypoxia and hyperoxia promotes the production of ROS. In addition, CO blocks the activity of the electron transport chain by binding ferrous iron to the active site of cytochrome C oxidase. As other complexes in the electron transport chain continue to transfer electrons, this leads to increased ROS production.[64] Overproduction of ROS can lead to significant DNA damage, resulting in 8-OHdG.[93] At the same time, the increase of ROS can enhance the expression of vasoconstrictor factors such as plasma endothelin by activating transcription factors such as nuclear factor κB, leading to the occurrence of hypertension.[94−97]

There is no evidence to suggest a direct contribution of 8-OHdG to hypertension. 8-OHdG is a marker produced in response to oxidative stress,[98] which suggests that oxidative stress may play a role in the association between CO and hypertension. Some gaseous pollutants (CO and NOx) indirectly affect DBP by affecting monocyte concentrations,[99] but the specific pathogenic process requires further study.

A meta-analysis examined the blood pressure health effects of acute and chronic exposure to PM_{10}, $PM_{2.5}$, O_3, CO, SO_2, and NOx and found a positive association between these pollutants and the prevalence of hypertension.[100] Inhaling PM induces changes in autonomic balance that are conducive to sympathetic nerve activity, promote systemic oxidative stress, induce systemic inflammation and cytokine production (TNF-α, IL-8), and lead to vascular dysfunction such as arterial vasoconstriction.[101−103] Although studies have shown that PM can lead to an increased risk of hypertension in humans, this view was not confirmed in this study. This may be due to respiratory exposure to different sources of PM, which have widely varying chemical compositions, resulting in varying associations with hypertension.[12,104,105] We conclude that for the population exposed to rural solid fuel combustion sources in China, gaseous pollutants, especially CO and O_3, exhibit more significant negative effects on hypertension than PM.

Respiratory exposure to O_3 and CO associated with solid fuel combustion promotes the development of SBP through the mediation of IL-10-u and 8-OHdG-b, respectively. This suggests that there may be a pathogenic mechanism for hypertension by which O_3 and CO can contribute to the elevation of SBP by inducing systemic inflammation and oxidative stress, which in turn enhances vasoconstrictor expression. This mechanism is particularly applicable to populations exposed to residential solid fuel combustion and high-salt diets. Similar findings regarding the ability of markers of inflammation and oxidative stress to mediate personal exposure to pollutants and disease were found in a study of the association between PAHs exposure and hyperuricemia in humans.[106] This means that more research can be done in this area in the future.

The results of the study suggest that residents in rural areas should minimize the use of solid fuels, and also pay attention to ventilation when using solid fuels on a daily basis in order to minimize the health impacts of solid fuel combustion. It is also recommended that the local population should maintain a low salt diet, which can help alleviate the onset or worsening of hypertension.

4. CONCLUSION

The mediating effect of household solid fuel combustion air pollutant exposure on blood pressure levels was first assessed. This study suggests that body inflammation and oxidative stress are important risk factors for elevated blood pressure in humans. And respiratory exposure to O_3 and CO associated with solid fuel combustion sources promoted the development of SBP through the mediation of IL-10-u and 8-OHdG-b. It suggests that there may be a pathogenic mechanism by which O_3 and CO contribute to the elevation of BP by inducing systemic inflammation and oxidative stress, which in turn enhances vasoconstrictor expression. This study also has some limitations. The relatively small sample size may limit the generalizability and extrapolation of the findings. Potential confounding factors, such as genetic factors, were not fully considered and apparently may also play a non-negligible role.

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

In the future, the sample size will be expanded and data on these potential variables will be collected and analyzed more systematically to fully assess the effects of air pollution on blood pressure. However, the result provides a certain scientific basis for further accelerating clean energy substitution in rural areas and preventing the occurrence of hypertension in China, and providing appropriate life advice to the local population. At the same time, it also provides a new perspective for promoting subsequent studies to deeply explore the relationship between environmental pollution and chronic diseases such as hypertension and cardiovascular diseases.

■ ASSOCIATED CONTENT

Data Availability Statement

Data will be made available on request.

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/envhealth.4c00182.

Participant selection process and criteria, biomarker analysis methods, data processing, personal exposure to air pollution sensor performance, and other supporting figure and tables involved in the study (PDF)

■ AUTHOR INFORMATION

Corresponding Author

Hongmei Xu − *Department of Environmental Science and Engineering, Xi'an Jiaotong University, Xi'an 710049, China; SKLLQG, Key Lab of Aerosol Chemistry & Physics, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710061, China;* orcid.org/0000-0002-4217-5066; Email: xuhongmei@xjtu.edu.cn

Authors

Meixuan Liu − *Department of Environmental Science and Engineering, Xi'an Jiaotong University, Xi'an 710049, China*

Yunxuan Gu − *Department of Environmental Science and Engineering, Xi'an Jiaotong University, Xi'an 710049, China*

Jianhong Zhu − *Second Affiliated Hospital of Medical College, Xi'an Jiaotong University, Xi'an 710004, China*

Hongai Zhang − *Department of Neonatology, Shanghai General Hospital Affiliated To Shanghai Jiao Tong University School Of Medicine, Shanghai 201620, China*

Hongwei Lu − *Second Affiliated Hospital of Medical College, Xi'an Jiaotong University, Xi'an 710004, China*

Jian Sun − *Department of Environmental Science and Engineering, Xi'an Jiaotong University, Xi'an 710049, China*

Zhenxing Shen − *Department of Environmental Science and Engineering, Xi'an Jiaotong University, Xi'an 710049, China; SKLLQG, Key Lab of Aerosol Chemistry & Physics, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710061, China;* orcid.org/0000-0002-1294-1751

Junji Cao − *SKLLQG, Key Lab of Aerosol Chemistry & Physics, Institute of Earth Environment, Chinese Academy of Sciences, Xi'an 710061, China*

Complete contact information is available at: https://pubs.acs.org/10.1021/envhealth.4c00182

Author Contributions

Meixuan Liu: Data curation, Investigation, Formal analysis, Writing original draft preparation; **Hongmei Xu:** Supervision, Conceptualization, Project administration, Funding acquisition, Writing-Original draft preparation; **Yunxuan Gu:** Investigation, Data Curation; **Jianhong Zhu:** Methodology, Investigation; **Hongai Zhang:** Methodology, Data Curation; **Hongwei Lu:** Methodology, Investigation; **Jian Sun:** Investigation, Resources; **Zhenxing Shen:** Investigation, Data Curation; **Junji Cao:** Investigation, Resources.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

This research was supported by the National Natural Science Foundation of China (42277422) and the Natural Science Foundation of Shaanxi Provincial (2023-JC-JQ-26). The open fund of the State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences (SKLLQG2425) is also thanked.

■ REFERENCES

(1) Zhu, X.; Yun, X.; Meng, W. J.; Xu, H. R.; Du, W.; Shen, G. F.; Cheng, H. F.; Ma, J. M.; Tao, S. Stacked Use and Transition Trends of Rural Household Energy in Mainland China. *Environ. Sci. Technol.* **2019**, *53* (1), 521−529.

(2) Zhang, B.; Wang, C.; Sun, J.; He, K.; Zou, H. J.; Xu, H. M.; Li, J. J.; Ho, K. F.; Shen, Z. X. Field measurements of $PM_{2.5}$ emissions from typical solid fuel combustion in rural households in Fenhe Basin, China. *Environmental Research* **2022**, *212*, 113361.

(3) Du, W.; Shen, G. F.; Chen, Y. C.; Zhu, X.; Zhuo, S. J.; Zhong, Q. R.; Qi, M.; Xue, C. Y.; Liu, G. Q.; Zeng, E.; Xing, B. S.; Tao, S. Comparison of air pollutant emissions and household air quality in rural homes using improved wood and coal stoves. *Atmos. Environ.* **2017**, *166*, 215−223.

(4) Weschler, C. J. Ozone in indoor environments: Concentration and chemistry. *Indoor Air* **2000**, *10* (4), 269−288.

(5) Townsend, C. L.; Maynard, R. L. Effects on health of prolonged exposure to low concentrations of carbon monoxide. *Occupational and Environmental Medicine* **2002**, *59* (10), 708−711.

(6) Kraft, M.; Eikmann, T.; Kappos, A.; Künzli, N.; Rapp, R.; Schneider, K.; Seitz, H.; Voss, J. U.; Wichmann, H. E. The German view: Effects of nitrogen dioxide on human health -: derivation of health-related short-term and long-term values. *International Journal of Hygiene and Environmental Health* **2005**, *208* (4), 305−318.

(7) Syc, M.; Horák, J.; Hopan, F.; Krpec, K.; Tomsej, T.; Ocelka, T.; Pekárek, V. Effect of Fuels and Domestic Heating Appliance Types on Emission Factors of Selected Organic Pollutants. *Environ. Sci. Technol.* **2011**, *45* (21), 9427−9434.

(8) Pryor, J. T.; Cowley, L. O.; Simonds, S. E. The Physiological Effects of Air Pollution: Particulate Matter, Physiology and Disease. *Frontiers in Public Health* **2022**, *10*, 882569.

(9) Gu, Y. X.; Xu, H. M.; Feng, R.; Cheng, Y.; Han, B.; Ho, K. F.; Wang, Z. X.; He, Y. S.; Qu, L. L.; Ho, S. S. H.; Sun, J.; Shen, Z. X.; Cao, J. J. Associations of personal exposure to domestic heating and cooking fuel emissions and epidemiological effects on rural residents in the Fenwei Plain, China. *Sci. Total Environ.* **2023**, *856*, 159217.

(10) Lushchak, V. I. Free radicals, reactive oxygen species, oxidative stress and its classification. *Chemico-Biological Interactions* **2014**, *224*, 164−175.

(11) Donaldson, K.; Mills, N.; MacNee, W.; Robinson, S.; Newby, D. Role of inflammation in cardiopulmonary health effects of PM. *Toxicol. Appl. Pharmacol.* **2005**, *207* (2 Suppl), 483−8.

(12) Binaya, K. C.; Mahapatra, P. S.; Thakker, D.; Henry, A. P.; Billington, C. K.; Sayers, I.; Puppala, S. P.; Hall, I. P. Proinflammatory Effects in Ex Vivo Human Lung Tissue of Respirable Smoke Extracts from Indoor Cooking in Nepal. *Annals of the American Thoracic Society* **2020**, *17* (6), 688−698.

(13) Derhaschnig, U.; Testori, C.; Riedmueller, E.; Aschauer, S.; Wolzt, M.; Jilma, B. Hypertensive emergencies are associated with

elevated markers of inflammation, coagulation, platelet activation and fibrinolysis. *Journal of Human Hypertension* **2013**, *27* (6), 368−373.
(14) Ravindra, K.; Kaur-Sidhu, M.; Mor, S. In Air Pollution in Rural Households Due to Solid Biomass Fuel Use and Its Health Impacts, *1st Asian Conference on Indoor Environmental Quality (ACIEQ), Indian Aviat Acad, New Delhi, INDIA, Feb 01−02, 2019*; Indian Aviat Acad, New Delhi, India, 2019; pp 27−33.
(15) Simkovich, S. M.; Goodman, D.; Roa, C.; Crocker, M. E.; Gianella, G. E.; Kirenga, B. J.; Wise, R. A.; Checkley, W. The health and social implications of household air pollution and respiratory diseases. *Npj Primary Care Respiratory Medicine* **2019**, *29*, 12.
(16) Dherani, M.; Pope, D.; Mascarenhas, M.; Smith, K. R.; Weber, M.; Bruce, N. Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis. *Bulletin of the World Health Organization* **2008**, *86* (5), 390−398.
(17) Hertel, S.; Viehmann, A.; Moebus, S.; Mann, K.; Bröcker-Preuss, M.; Möhlenkamp, S.; Nonnemacher, M.; Erbel, R.; Jakobs, H.; Memmesheimer, M.; Jöckel, K. H.; Hoffmann, B. Influence of short-term exposure to ultrafine and fine particles on systemic inflammation. *European Journal of Epidemiology* **2010**, *25* (8), 581−592.
(18) Kusche-Vihrog, K.; Urbanova, K.; Blanqué, A.; Wilhelmi, M.; Schillers, H.; Kliche, K.; Pavenstädt, H.; Brand, E.; Oberleithner, H. C-Reactive Protein Makes Human Endothelium Stiff and Tight. *Hypertension* **2011**, *57* (2), 231−237.
(19) Brook, R. D.; Urch, B.; Dvonch, J. T.; Bard, R. L.; Speck, M.; Keeler, G.; Morishita, M.; Marsik, F. J.; Kamal, A. S.; Kaciroti, N.; Harkema, J.; Corey, P.; Silverman, F.; Gold, D. R.; Wellenius, G.; Mittleman, M. A.; Rajagopalan, S.; Brook, J. R. Insights Into the Mechanisms and Mediators of the Effects of Air Pollution Exposure on Blood Pressure and Vascular Function in Healthy Humans. *Hypertension* **2009**, *54* (3), 659−667.
(20) Kim, K. H.; Jahan, S. A.; Kabir, E. A review of diseases associated with household air pollution due to the use of biomass fuels. *Journal of Hazardous Materials* **2011**, *192* (2), 425−431.
(21) Zhang, M.; Shi, Y.; Zhou, B.; Huang, Z. J.; Zhao, Z. P.; Li, C.; Zhang, X.; Han, G. Y.; Peng, K.; Li, X. H.; Wang, Y. F.; Ezzati, M.; Wang, L. M.; Li, Y. C. Prevalence, awareness, treatment, and control of hypertension in China, 2004−18: findings from six rounds of a national survey. *Bmj-British Medical Journal* **2023**, *380*, e071952.
(22) *Global report on hypertension:The race against a silent killer*. In World Health Organization 2023.
(23) He, J.; Gu, D.; Chen, J.; Wu, X.; Kelly, T. N.; Huang, J. F.; Chen, J. C.; Chen, C. S.; Bazzano, L. A.; Reynolds, K.; Whelton, P. K.; Klag, M. J. Premature deaths attributable to blood pressure in China: a prospective cohort study. *Lancet* **2009**, *374* (9703), 1765−1772.
(24) Chen, W. W.; Gao, R. L.; Liu, L. S.; Zhu, M. L.; Wang, W.; Wang, Y. J.; Wu, Z. S.; Li, H. J.; Gu, D. F.; Yang, Y. J.; Zheng, Z.; Jiang, L. X.; Hu, S. S.; Writing, G. China cardiovascular diseases report 2015: a summary. *Journal of Geriatric Cardiology* **2017**, *14* (1), 1−10.
(25) Schöttker, B.; Saum, K. U.; Jansen, E.; Holleczek, B.; Brenner, H. Associations of metabolic, inflammatory and oxidative stress markers with total morbidity and multi-morbidity in a large cohort of older German adults. *Age and Ageing* **2016**, *45* (1), 127−135.
(26) Bautista, L. E.; Vera, L. M.; Arenas, I. A.; Gamarra, G. Independent association between inflammatory markers (C-reactive protein, interleukin-6, and TNF-α) and essential hypertension. *Journal of Human Hypertension* **2005**, *19* (2), 149−154.
(27) Zhang, Z. L.; Zhao, L.; Zhou, X. Y.; Meng, X.; Zhou, X. L. Role of inflammation, immunity, and oxidative stress in hypertension: New insights and potential therapeutic targets. *Frontiers in Immunology* **2023**, *13*, 1098725.
(28) Di Minno, A.; Turnu, L.; Porro, B.; Squellerio, I.; Cavalca, V.; Tremoli, E.; Di Minno, M. N. D. 8-Hydroxy-2-Deoxyguanosine Levels and Cardiovascular Disease: A Systematic Review and Meta-Analysis of the Literature. *Antioxidants & Redox Signaling* **2016**, *24* (10), 548−555.
(29) Sun, Y. T.; Gong, Y.; Zhu, R. H.; Liu, X. K.; Zhu, Y.; Wang, Y.; Qiu, Q. Q.; Qi, L.; Liang, J. Relationship between white blood cells and hypertension in Chinese adults: The Cardiometabolic Risk in Chinese (CRC) study. *Clinical and Experimental Hypertension* **2015**, *37* (7), 594−598.
(30) Businge, D.; Evans, R. G.; Arabshahi, S.; Riddell, M. A.; Srikanth, V. K.; Kartik, K.; Kalyanram, K.; Zhu, X.; Suresh, O.; Thrift, A. G. Association of hypertension with infection and inflammation in a setting of disadvantage in rural India. *Journal of Human Hypertension* **2022**, *36* (11), 1011−1020.
(31) Zhou, S.; Guo, C. S.; Dai, Y. Y.; Pan, X. H.; Luo, X. Y.; Qin, P. Z.; Tan, L. Association between polycyclic aromatic hydrocarbon exposure and liver function: The mediating roles of inflammation and oxidative stress. *Environ. Pollut.* **2024**, *342*, 123068.
(32) Feng, R.; Xu, H. M.; He, K. L.; Wang, Z. X.; Han, B.; Lei, R. H.; Ho, K. F.; Niu, X. Y.; Sun, J.; Zhang, B.; Liu, P. P.; Shen, Z. X. Effects of domestic solid fuel combustion emissions on the biomarkers of homemakers in rural areas of the Fenwei Plain, China. *Ecotoxicology and Environmental Safety* **2021**, *214*, 112104.
(33) Li, H.; Wang, H.; Yan, Q.; Cheng, M.; Li, Y.; Zhang, W. Chemical Composition Characteristics and Source Apportionment of PM_(2.5) in the Fenwei Plain in Autumn and Winter. *Research of. Res. Environmental Sciences* **2023**, *36* (3), 449−459.
(34) Sarnat, J. A.; Brown, K. W.; Schwartz, J.; Coull, B. A.; Koutrakis, P. Ambient gas concentrations and personal particulate matter exposures - Implications for studying the health effects of particles. *Epidemiology* **2005**, *16* (3), 385−395.
(35) Bai, Y. L.; Xu, H. M.; Feng, R.; Gu, Y. X.; Liu, M. X.; Sun, J.; Qu, L. L.; Ho, S. S. H.; Shen, Z. X.; Cao, J. J. Environmental and health impacts of household energy conversion on PAHs and their derivatives in PM2.5 in typical areas of northern China. *Sci. Total Environ.* **2023**, *888*, 164187.
(36) Li, J. M.; Yang, B. Y.; Liu, L.; Gu, J. J.; Cao, M. Y.; Wu, L. L.; He, J. W. Relationship between air pollutants and spontaneous abortion in a coal resource valley city: a retrospective cohort study. *Journal of Maternal-Fetal & Neonatal Medicine* **2023**, *36* (2), 2281876.
(37) Hirano, T.; Yasukawa, K.; Harada, H.; Taga, T.; Watanabe, Y.; Matsuda, T.; Kashiwamura, S.; Nakajima, K.; Koyama, K.; Iwamatsu, A.; Tsunasawa, S.; Sakiyama, F.; Matsui, H.; Takahara, Y.; Taniguchi, T.; Kishimoto, T. Complementary-DNA for a Novel Human Interleukin (Bsf-2) That Induces Lymphocytes-B to Produce Immunoglobulin. *Nature* **1986**, *324* (6092), 73−76.
(38) Moore, K. W.; Malefyt, R. D.; Coffman, R. L.; O'Garra, A. Interleukin-10 and the interleukin-10 receptor. *Annu. Rev. Immunol.* **2001**, *19*, 683−765.
(39) Steeland, S.; Libert, C.; Vandenbroucke, R. E. A New Venue of TNF Targeting. *International Journal of Molecular Sciences* **2018**, *19* (5), 1442.
(40) Valavanidis, A.; Vlachogianni, T.; Fiotakis, C. 8-hydroxy-2' -deoxyguanosine (8-OHdG): A Critical Biomarker of Oxidative Stress and Carcinogenesis. *Journal of Environmental Science and Health Part C- Environmental Carcinogenesis & Ecotoxicology Reviews* **2009**, *27* (2), 120−139.
(41) Pappu, R.; Schwab, S. R.; Cornelissen, I.; Pereira, J. P.; Regard, J. B.; Xu, Y.; Camerer, E.; Zheng, Y. W.; Huang, Y.; Cyster, J. G.; Coughlin, S. R. Promotion of lymphocyte egress into blood and lymph by distinct sources of sphingosine-1-phosphate. *Science* **2007**, *316* (5822), 295−298.
(42) Jakubzick, C. V.; Randolph, G. J.; Henson, P. M. Monocyte differentiation and antigen-presenting functions. *Nature Reviews Immunology* **2017**, *17* (6), 349−362.
(43) Schmidschonbein, G. W.; Seiffge, D.; Delano, F. A.; Shen, K.; Zweifach, B. W. Leukocyte counts and activation in spontaneously hypertensive and normotensive rats. *Hypertension* **1991**, *17* (3), 323−330.
(44) Hayes, A. F. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford Press: New York, NY, US, 2013; p xvii, 507−xvii, 507.

(45) Wen, Z.; Ye, B. Analyses of Mediating Effects: The Development of Methods and Models. *Advances in Psychological Science* **2014**, *22* (5), 731−745.
(46) Wen, Z.; Zhang, L.; Hou, J.; Liu, H. Testing and application of the mediating effects. *Acta Psychologica Sinica* **2004**, *36* (5), 614−620.
(47) Zhao, X. S.; Lynch, J. G.; Chen, Q. M. Reconsidering Baron and Kenny: Myths and Truths about Mediation Analysis. *Journal of Consumer Research* **2010**, *37* (2), 197−206.
(48) Lee, S.; Yu, S.; Kim, S. Evaluation of Potential Average Daily Doses (ADDs) of $PM_{2.5}$ for Homemakers Conducting Pan-Frying Inside Ordinary Homes under Four Ventilation Conditions. *International Journal of Environmental Research and Public Health* **2017**, *14* (1), 78.
(49) Kim, Y.; Shin, D.; Hong, K. J.; Lee, G.; Kim, S. B.; Park, I.; Han, B.; Hwang, J. Efficient Energy Saving Scenarios for Indoor $PM_{2.5}$ Management in an Apartment of South Korea. *Toxics* **2022**, *10* (10), 609.
(50) Whitworth, J.; Canny, J.; Yao, C. H.; Christensen, B.; Cooper, R. S.; Kadiri, S.; Hill, S.; Kaplan, N.; Kuschnir, E.; Lexchin, J.; Mendis, S.; Poulter, N.; Psaty, B. M.; Rahn, K. H.; Sheps, S. G.; Whitworth, J.; Yach, D.; Bengoa, R.; Ramsay, L.; Kaplan, N.; Mendis, S.; Poulter, N.; Afridi, I.; World Health, O.. 2003 World Health Organization (WHO)/International Society of Hypertension (ISH) statement on management of hypertension. *Journal of Hypertension* **2003**, *21* (11), 1983−1992.
(51) Song, H. X.; Feng, D.; Wang, R. X.; Yang, J.; Li, Y. Q.; Gao, J. L.; Wang, Z.; Yan, Z. Q.; Long, C. X.; Zhou, J. W.; Feng, Z. C. The urban-rural disparity in the prevalence and risk factors of hypertension among the elderly in China a cross-sectional study. *Peerj* **2019**, *7*, e8015.
(52) Xing, L. Y.; Jing, L.; Tian, Y. M.; Lin, M.; Du, Z.; Yan, H.; Ren, G. C.; Dong, Y. N.; Sun, Q.; Liu, S. Urban-Rural disparities in status of hypertension in northeast China: a population-based study, 2017−2019. *Clinical Epidemiology* **2019**, *11*, 801−820.
(53) Yin, M. H.; Liu, C. P. Estimation of Mean Variation in Prediction Probability for Prevalence of Hypertension in Middle-Aged and Older Chinese Using Probit Model. *Asia-Pacific Journal of Public Health* **2020**, *32* (4), 194−200.
(54) Liu, X.; Xiu, J.; Li, X. Influencing factors of hypertension prevalence among middle-aged and elderly people in China. *China Journal of Public Health* **2018**, *34* (6), 795−797.
(55) Standards for indoor air quality. In *State Administration for Market Regulation*; Standardization Administration: 2022; Vol. GB/T 18883−2022, p 52.
(56) Ruscio, A.; Kazanc, F.; Levendis, Y. A. Comparison of Fine Ash Emissions Generated from Biomass and Coal Combustion and Valuation of Predictive Furnace Deposition Indices: A Review. *Journal of Energy Engineering* **2016**, *142* (2), E4015007.
(57) Hahad, O.; Lelieveld, J.; Birklein, F.; Lieb, K.; Daiber, A.; Münzel, T. Ambient Air Pollution Increases the Risk of Cerebrovascular and Neuropsychiatric Disorders through Induction of Inflammation and Oxidative Stress. *International Journal of Molecular Sciences* **2020**, *21* (12), 4306.
(58) Brucker, N.; Moro, A. M.; Charao, M. F.; Durgante, J.; Freitas, F.; Baierle, M.; Nascimento, S.; Gauer, B.; Bulcao, R. P.; Bubols, G. B.; Ferrari, P. D.; Thiesen, F. V.; Gioda, A.; Duarte, M.; de Castro, I.; Saldiva, P. H.; Garcia, S. C. Biomarkers of occupational exposure to air pollution, inflammation and oxidative damage in taxi drivers. *Sci. Total Environ.* **2013**, *463*, 884−893.
(59) Li, H. C.; Cai, J.; Chen, R. J.; Zhao, Z. H.; Ying, Z. K.; Wang, L.; Chen, J. M.; Hao, K.; Kinney, P. L.; Chen, H. L.; Kan, H. D. Particulate Matter Exposure and Stress Hormone Levels A Randomized, Double-Blind, Crossover Trial of Air Purification. *Circulation* **2017**, *136* (7), 618.
(60) Dong, W. M.; Lewtas, J.; Luster, M. I. Role of endotoxin in tumor necrosis factor alpha expression from alveolar macrophages treated with urban air particles. *Experimental Lung Research* **1996**, *22* (5), 577−592.
(61) Ayyagari, V. N.; Januszkiewicz, A.; Nath, J. Pro-inflammatory responses of human bronchial epithelial cells to acute nitrogen dioxide exposure. *Toxicology* **2004**, *197* (2), 148−164.
(62) Steenhof, M.; Janssen, N. A. H.; Strak, M.; Hoek, G.; Gosens, I.; Mudway, I. S.; Kelly, F. J.; Harrison, R. M.; Pieters, R. H. H.; Cassee, F. R.; Brunekreef, B. Air pollution exposure affects circulating white blood cell counts in healthy subjects: the role of particle composition, oxidative potential and gaseous pollutants - the RAPTES project. *Inhalation Toxicology* **2014**, *26* (3), 141−165.
(63) Gruzieva, O.; Merid, S. K.; Gref, A.; Gajulapuri, A.; Lemonnier, N.; Ballereau, S.; Gigante, B.; Kere, J.; Auffray, C.; Melén, E.; Pershagen, G. Exposure to Traffic-Related Air Pollution and Serum Inflammatory Cytokines in Children. *Environ. Health Perspect.* **2017**, *125* (6), 067007.
(64) Cha, Y. S.; Chang, J. S.; Kim, H.; Park, K. S. Application of Mitochondrial and Oxidative Stress Biomarkers in the Evaluation of Neurocognitive Prognosis Following Acute Carbon Monoxide Poisoning. *Metabolites* **2022**, *12* (3), 201.
(65) Baeza, A.; Marano, F. Air pollution and respiratory diseases: a central role for oxidative stress. *M S-Medecine Sciences* **2007**, *23* (5), 497−501.
(66) Chaitanya, R. K.; Shashank, K.; Sridevi, P. Oxidative Stress in Invertebrate Systems. *Free Radicals and Diseases*; 2016; pp 19−36.
(67) Bello-Medina, P. C.; Rodriguez-Martinez, E.; Prado-Alcala, R. A.; Rivas-Arancibia, S. Ozone pollution, oxidative stress, synaptic plasticity, and neurodegeneration. *Neurologia (Barcelona, Spain)* **2022**, *37* (4), 277−286.
(68) Henriquez, A. R.; Williams, W.; Snow, S. J.; Schladweiler, M. C.; Fisher, C.; Hargrove, M. M.; Alewel, D.; Colonna, C.; Gavett, S. H.; Miller, C. N.; Kodavanti, U. P. The dynamicity of acute ozone-induced systemic leukocyte trafficking and adrenal-derived stress hormones. *Toxicology* **2021**, *458*, 152823.
(69) Li, A. F. Y.; Richters, A. Ambient level ozone effects on subpopulations of thymocytes and spleen lymphocytes-T. *Arch. Environ. Health* **1991**, *46* (1), 57−63.
(70) Dutta, A.; Ray, M. R.; Banerjee, A. Systemic inflammatory changes and increased oxidative stress in rural Indian women cooking with biomass fuels. *Toxicol. Appl. Pharmacol.* **2012**, *261* (3), 255−262.
(71) Laratta, C. R.; Kendzerska, T.; Carlsten, C.; Brauer, M.; van Eeden, S. F.; Allen, A.; Fox, N.; Peres, B. U.; Ayas, N. T. Air Pollution and Systemic Inflammation in Patients With Suspected OSA Living in an Urban Residential Area. *Chest* **2020**, *158* (4), 1713−1722.
(72) Goto, Y.; Ishii, H.; Hogg, J. C.; Shih, C. H.; Yatera, K.; Vincent, R.; van Eeden, S. F. Particulate matter air pollution stimulates monocyte release from the bone marrow. *American Journal of Respiratory and Critical Care Medicine* **2004**, *170* (8), 891−897.
(73) Liu, G. H.; Yan, X. L.; Sedykh, A.; Pan, X. J.; Zhao, X. L.; Yan, B.; Zhu, H. Analysis of model $PM_{2.5}$-induced inflammation and cytotoxicity by the combination of a virtual carbon nanoparticle library and computational modeling. *Ecotoxicology and Environmental Safety* **2020**, *191*, 110216.
(74) Zhu, J.; Zhao, Y. M.; Gao, Y. Z.; Li, C. Y.; Zhou, L. T.; Qi, W.; Zhang, Y. Z.; Ye, L. Effects of Different Components of $PM_{2.5}$ on the Expression Levels of NF-B Family Gene mRNA and Inflammatory Molecules in Human Macrophage. *International Journal of Environmental Research and Public Health* **2019**, *16* (8), 1408.
(75) Ma, H. M.; Li, J.; Wan, C.; Liang, Y. H.; Zhang, X. Y.; Dong, G. H.; Hu, L. W.; Yang, B. Y.; Zeng, X. W.; Su, T.; Lu, S. Y.; Chen, S. J.; Khorram, M. S.; Sheng, G. Y.; Wang, X. M.; Mai, B. X.; Yu, Z. Q.; Zhang, G. Inflammation Response of Water-Soluble Fractions in Atmospheric Fine Particulates: A Seasonal Observation in 10 Large Chinese Cities. *Environ. Sci. Technol.* **2019**, *53* (7), 3782−3790.
(76) Kim, I.; Park, K.; Lee, K.; Park, M.; Lim, H.; Shin, H.; Kim, S. D. Application of various cytotoxic endpoints for the toxicity prioritization of fine dust (PM2.5) sources using a multi-criteria decision-making approach. *Environmental Geochemistry and Health* **2020**, *42* (6), 1775−1788.

https://doi.org/10.1021/envhealth.4c00182
Environ. Health 2025, 3, 458−468

(77) Patrick, D. M.; Van Beusecum, J. P.; Kirabo, A. The role of inflammation in hypertension: novel concepts. *Current Opinion in Physiology* **2021**, *19*, 92−98.
(78) Ito, H.; Ohshima, A.; Tsuzuki, M.; Ohto, N.; Takao, K.; Hijii, C.; Yanagawa, M.; Ogasawara, M.; Nishioka, K. Association of serum tumour necrosis factor-α with serum low-density lipoprotein-cholesterol and blood pressure in apparently healthy Japanese women. *Clin. Exp. Pharmacol. Physiol.* **2001**, *28* (3), 188−192.
(79) Dalekos, G. N.; Elisaf, M.; Bairaktari, E.; Tsolas, O.; Siamopoulos, K. C. Increased serum levels of interleukin-1 beta in the systemic circulation of patients with essential hypertension: Additional risk factor for atherogenesis in hypertensive patients? *Journal of Laboratory and Clinical Medicine* **1997**, *129* (3), 300−308.
(80) Bermudez, E. A.; Rifai, N.; Buring, J.; Manson, J. E.; Ridker, P. A. Interrelationships among circulating interleukin-6, C-reactive protein, and traditional cardiovascular risk factors in women. *Arteriosclerosis Thrombosis and Vascular Biology* **2002**, *22* (10), 1668−1673.
(81) Negishi, H.; Ikeda, K.; Kuga, S.; Noguchi, T.; Kanda, T.; Njelekela, M.; Liu, L. J.; Miki, T.; Nara, Y.; Sato, T.; Mashalla, Y.; Mtabaji, J.; Yamori, Y. The relation of oxidative DNA damage to hypertension and other cardiovascular risk factors in Tanzania. *Journal of Hypertension* **2001**, *19* (3), 529−533.
(82) Coogan, P. F.; White, L. F.; Yu, J.; Brook, R. D.; Burnett, R. T.; Marshall, J. D.; Bethea, T. N.; Rosenberg, L.; Jerrett, M. Long-Term Exposure to NO_2 and Ozone and Hypertension Incidence in the Black Women's Health Study. *American Journal of Hypertension* **2017**, *30* (4), 367−372.
(83) Liu, C.; Yin, P.; Chen, R. J.; Meng, X.; Wang, L. J.; Niu, Y.; Lin, Z. J.; Liu, Y. N.; Liu, J. M.; Qi, J. L.; You, J. L.; Kan, H. D.; Zhou, M. G. Ambient carbon monoxide and cardiovascular mortality: a nationwide time-series analysis in 272 cities in China. *Lancet Planetary Health* **2018**, *2* (1), E12−E18.
(84) Chen, C. C.; Yang, C. Y. Association between gaseous air pollution and hospital admissions for hypertension in Taipei, Taiwan. *Journal of Toxicology and Environmental Health-Part a-Current Issues* **2018**, *81* (4), 53−59.
(85) Rivas-Arancibia, S.; Guevara-Guzmán, R.; López-Vidal, Y.; Rodríguez-Martínez, E.; Zanardo-Gomes, M.; Angoa-Pérez, M.; Raisman-Vozari, R. Oxidative Stress Caused by Ozone Exposure Induces Loss of Brain Repair in the Hippocampus of Adult Rats. *Toxicol. Sci.* **2010**, *113* (1), 187−197.
(86) Guzik, T. J.; Hoch, N. E.; Brown, K. A.; McCann, L. A.; Rahman, A.; Dikalov, S.; Goronzy, J.; Weyand, C.; Harrison, D. G. Role of the T cell in the genesis of angiotensin II-induced hypertension and vascular dysfunction. *Journal of Experimental Medicine* **2007**, *204* (10), 2449−2460.
(87) Singh, P.; Castillo, A.; Islam, M. T.; Majid, D. S. A. Evidence for Prohypertensive, Proinflammatory Effect of Interleukin-10 During Chronic High Salt Intake in the Condition of Elevated Angiotensin II Level. *Hypertension* **2017**, *70* (4), 839.
(88) Hipgrave, D. B.; Chang, S. Y.; Li, X. W.; Wu, Y. N. Salt and Sodium Intake in China. *Jama-Journal of the American Medical Association* **2016**, *315* (7), 703−705.
(89) Yun, X.; Shen, G. F.; Shen, H. Z.; Meng, W. J.; Chen, Y. L.; Xu, H. R.; Ren, Y.; Zhong, Q. R.; Du, W.; Ma, J. M.; Cheng, H. F.; Wang, X. L.; Liu, J. F.; Wang, X. J.; Li, B. G.; Hu, J. Y.; Wan, Y.; Tao, S. Residential solid fuel emissions contribute significantly to air pollution and associated health impacts in China. *Science Advances* **2020**, *6* (44), eaba7621.
(90) da Silva, G. Hydroxyl radical regeneration in the photochemical oxidation of glyoxal: kinetics and mechanism of the $HC(O)CO + O_2$ reaction. *Phys. Chem. Chem. Phys.* **2010**, *12* (25), 6698−6705.
(91) Wang, T.; Xue, L. K.; Brimblecombe, P.; Lam, Y. F.; Li, L.; Zhang, L. Ozone pollution in China: A review of concentrations, meteorological influences, chemical precursors, and effects. *Sci. Total Environ.* **2017**, *575*, 1582−1596.
(92) Akyol, S.; Erdogan, S.; Idiz, N.; Celik, S.; Kaya, M.; Ucar, F.; Dane, S.; Akyol, O. The role of reactive oxygen species and oxidative stress in carbon monoxide toxicity: An in-depth analysis. *Redox Report* **2014**, *19* (5), 180−189.
(93) Campagnaro, B. P.; Tonini, C. L.; Nogueira, B. V.; Casarini, D. E.; Vasquez, E. C.; Meyrelles, S. S. DNA damage and augmented oxidative stress in bone marrow mononuclear cells from Angiotensin-dependent hypertensive mice. *International journal of hypertension* **2013**, *2013*, 305202.
(94) Brook, R. D.; Brook, J. R.; Urch, B.; Vincent, R.; Rajagopalan, S.; Silverman, F. Inhalation of fine particulate air pollution and ozone causes acute arterial vasoconstriction in healthy adults. *Circulation* **2002**, *105* (13), 1534−1536.
(95) Taniyama, Y.; Griendling, K. K. Reactive oxygen species in the vasculature - Molecular and cellular mechanisms. *Hypertension* **2003**, *42* (6), 1075−1081.
(96) Urch, B.; Brook, J. R.; Wasserstein, D.; Brook, R. D.; Rajagopalan, S.; Corey, P.; Silverman, F. Relative contributions of $PM_{2.5}$ chemical constituents to acute arterial vasoconstriction in humans. *Inhalation Toxicology* **2004**, *16* (6−7), 345−352.
(97) Sanidas, E.; Papadopoulos, D. P.; Grassos, H.; Velliou, M.; Tsioufis, K.; Barbetseas, J.; Papademetriou, V. Air pollution and arterial hypertension. A new risk factor is in the air. *The. Journal of the American Society of Hypertension* **2017**, *11* (11), 709−715.
(98) Yun, X.; Shen, G.; Shen, H.; Meng, W.; Chen, Y.; Xu, H.; Ren, Y.; Zhong, Q.; Du, W.; Ma, J.; Cheng, H.; Wang, X.; Liu, J.; Wang, X.; Li, B.; Hu, J.; Wan, Y.; Tao, S. *Science Advances* **2020**, *6* (44), eaba7621.
(99) Prunicki, M.; Cauwenberghs, N.; Ataam, J. A.; Movassagh, H.; Kim, J. B.; Kuznetsova, T.; Wu, J. C.; Maecker, H.; Haddad, F.; Nadeau, K. Immune biomarkers link air pollution exposure to blood pressure in adolescents. *Environmental Health-Glob* **2020**, *19* (1), 108.
(100) Cai, Y. Y.; Zhang, B.; Ke, W. X.; Feng, B. X.; Lin, H. L.; Xiao, J. P.; Zeng, W. L.; Li, X.; Tao, J.; Yang, Z. Y.; Ma, W. J.; Liu, T. Associations of Short-Term and Long-Term Exposure to Ambient Air Pollutants With Hypertension A Systematic Review and Meta-Analysis. *Hypertension* **2016**, *68* (1), 62.
(101) Donaldson, K.; Stone, V.; Borm, P. J. A.; Jimenez, L. A.; Gilmour, P. S.; Schins, R. P. F.; Knaapen, A. M.; Rahman, I.; Faux, S. P.; Brown, D. M.; MacNee, W. Oxidative stress and calcium signaling in the adverse effects of environmental particles (PM_{10}). *Free Radical Biol. Med.* **2003**, *34* (11), 1369−1382.
(102) Brook, R. D. You are what you breathe: Evidence linking air pollution and blood pressure. *Current Hypertension Reports* **2005**, *7* (6), 427−434.
(103) Brook, R. D.; Rajagopalan, S.; Pope, C. A.; Brook, J. R.; Bhatnagar, A.; Diez-Roux, A. V.; Holguin, F.; Hong, Y. L.; Luepker, R. V.; Mittleman, M. A.; Peters, A.; Siscovick, D.; Smith, S. C.; Whitsel, L.; Kaufman, J. D.; Amer Heart Assoc Council, E.; Council Kidney Cardiovasc, D.; Council Nutr Phys Activity, M.. Particulate Matter Air Pollution and Cardiovascular Disease An Update to the Scientific Statement From the American Heart Association. *Circulation* **2010**, *121* (21), 2331−2378.
(104) Bangia, K. S.; Symanski, E.; Strom, S. S.; Bondy, M. A cross-sectional analysis of polycyclic aromatic hydrocarbons and diesel particulate matter exposures and hypertension among individuals of Mexican origin. *Environmental Health* **2015**, *14*, 51.
(105) Okokon, E. O.; Yli-Tuomi, T.; Siponen, T.; Tiittanen, P.; Turunen, A. W.; Kangas, L.; Karppinen, A.; Kukkonen, J.; Lanki, T. Heterogeneous Urban Exposures and Prevalent Hypertension in the Helsinki Capital Region, Finland. *International Journal of Environmental Research and Public Health* **2021**, *18* (3), 1196.
(106) Guo, C. F.; Liu, X.; Liao, X. J.; Wu, H. M.; Zhang, Z. R.; Wu, D. H.; Ma, R.; Huang, Y. S.; Zhao, N.; Xiao, Y. M.; Deng, Q. F. Associations of co-exposure to polycyclic aromatic hydrocarbons and metals with hyperuricemia risk in Chinese coke oven workers: Mediating roles of oxidative damage*. *Environ. Pollut.* **2023**, *318*, 120891.