



Cooking fuel and the risk of pregnancy-induced hypertension in Lanzhou, China: A birth cohort study

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Abstract

Background: The relationship between the solid fuels and the occurrence of pregnancy-induced hypertension (PIH) is inconclusive. **Methods:** A birth cohort study of 10,452 pregnant women without chronic hypertension was conducted from 2010 to 2012 at the Gansu Provincial Maternity and Child Care Hospital in Lanzhou, China. Multivariable logistic regression models were used to assess the relationship. **Results:** Compared to pregnant women using gas as cooking fuel, pregnant women using coal (OR=2.55, 95% CI: 1.85-3.51) and biomass (OR=3.58, 95% CI: 2.29-5.60) were associated with an increased risk of PIH, gestational hypertension (biomass: OR=3.38, 95% CI: 1.68-6.80), and preeclampsia (coal: OR=2.89, 95% CI: 1.98-4.21; biomass: OR=3.38, 95% CI: 1.95-5.84). The relationship between cooking fuel and PIH is modified by maternal age ($p<0.0001$), pre-pregnancy BMI ($p<0.0001$), gestational weight gain ($p<0.0001$), parity ($p<0.0001$), and multiple birth ($p<0.0001$). **Conclusions:** During pregnancy, exposure to coal or biomass was associated with an increased risk of PIH and preeclampsia.

Keywords: cooking fuel; pregnancy-induced hypertension; preeclampsia; birth cohort; China.

Practical Application: Exposure to coal or biomass was associated with an increased risk of PIH and preeclampsia during pregnancy.

1 Introduction

Solid fuels, such as coal and biomass (wood, crop residues), are widely used for cooking in worldwide, approximately half of the world's population (International Energy Agency & Organisation for Economic Cooperation and Development, 2004). In China, gas, biomass, solar/electricity, and coal, the main energy fuels for cooking, are used by 44.8%, 32.1%, 11.7% and 11.3% of households, respectively. (Duan et al., 2014) Studies found that indoor PM_{2.5} concentrations is higher than that in outdoor air due to inefficient combustion of solid fuel, especially in rural areas. (Li et al., 2016; Shen et al., 2010) Indoor air pollution (IAP) is associated with illness and premature deaths and more than 800,000 deaths were caused in 2013 by IAP in China (Institute for Health Metrics and Evaluation, 2016). Cohort studies found that IAP from solid fuels has been proved to be associated with the increases risk of blood pressure, (Baumgartner et al., 2011; Clark et al., 2011) and chronic hypertension (Dutta & Ray, 2012; Lee et al., 2012) in non-pregnant populations. However, there is a paucity of studies on the correlation between solid fuels and the risk of pregnancy-induced hypertension (PIH).

Hypertension is one of the most common complications during pregnancy, with 10% of all pregnancies in the population worldwide having hypertension. (Ghulmiyyah & Sibai, 2012) PIH are classified into 4 categories: 1) preeclampsia-eclampsia, 2) chronic hypertension (of any cause), 3) preeclampsia (PE) superimposed on chronic hypertension, 4) gestational hypertension (GH) (American College of Obstetricians and Gynecologists & Task Force on Hypertension in Pregnancy, 2013). PIH can lead to

severe maternal and fetal complications, such as cardiovascular disease, liver and kidney failure, placental abruption, preterm delivery, fetal distress, fetal growth restriction and stillbirth, and also increase lifetime risk of cardiovascular disease of both maternal and their children. (Grandi et al., 2017; Alsnes et al., 2017) Few studies reported the link between cooking fuel and PIH, and the results have been inconsistent. (Wylie et al., 2015; Agrawal & Yamamoto, 2015) Furthermore, no study has been conducted in a Chinese population, where solid fuels are used as the main energy fuels for cooking. To further investigate the association between cooking fuel and risk of PIH, we conducted a birth cohort study in Lanzhou, China.

For the first time, the associations between types of cooking fuels and the risk of PIH were evaluated in a Chinese population, in which an increased risk of PIH among women who using coal or biomass for cooking compared to use of gas, and the risk varies by PIH subtypes were found.

2 Methods

The birth cohort study was conducted on 10,542 pregnant women, aged 18 years or older, with no history of mental illness and gestational ages ≥ 20 weeks, from 2010 to 2012 at the Gansu Provincial Maternity and Child Care Hospital in Lanzhou, China. (Qiu et al., 2014; Huang et al., 2016; Shao et al., 2017) Upon obtaining written consent, an interview was conducted at the hospital using a standardized and structured questionnaire to collect information on demographic factors, reproductive

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history, medical condition and medication use, lifestyle factors, occupational exposures, and residential history. The majority of the participated women (84%) were interviewed within 3 days after delivery, while others were interviewed within 2 days before delivery. Information on maternal complications was got from the medical records. The final sample was 10,452 after exclusion of women who delivered still birth (n=53) and who had chronic hypertension (n=37). All study procedures were approved by the human investigation committees at the Gansu Provincial Maternity and Child Care Hospital and Yale University.

Information regarding cooking fuel used in current and each past residence was collected, including the duration of stay in each residence (date from move in and move out), the type of fuel used for cooking in each residence (gas, electromagnetic, coal, biomass and others), ventilation during cooking, and the most common way of cooking (deep fried, pan fried, braised, steaming, simmer, and other) before and during pregnancy.

PIH cases included GH, PE and eclampsia. GH was defined as hypertension (blood pressure $\geq 140/90$ mmHg) and no proteinuria was measured twice at a 6h interval after 20 weeks of gestation. PE was defined as hypertension with proteinuria (≥ 300 mg per 24 hour) or proteinuria of at least 1+ on dipstick test after 20 weeks of gestation. PE was further classified as mild PE (M-PE), severe PE (S-PE), early-onset PE (EOPE), and late-onset PE (LOPE). M-PE was diagnosed as hypertension ($\geq 140/90$ mmHg and $< 160/110$ mmHg) and proteinuria ($\geq 1+$ and $< 2+$ on dipstick test in two urine samples) without serious symptoms. S-PE was diagnosed as hypertension ($\geq 160/110$ mmHg) and proteinuria ($\geq 2+$ on dipstick test in two urine samples) with symptoms, such as headache, blurred vision, epigastric burning pain, decreased urine output, decreased or absent fetal kick. EOPE was defined as PE diagnosed before 34 weeks of gestation while LOPE was defined as PE diagnosed after 34 weeks of gestation. Eclampsia was defined as a new onset of seizures association with PE.

Gestational weight gain (GWG) was calculated by subtracting pre-pregnancy weight from the weight at delivery. Pre-pregnancy weight was self-reported. According to the US Institute of Medicine (IOM) GWG Guidelines (Institute of Medicine & National Research Council, 2009), GWG was categorized into insufficient, sufficient and excessive. Sufficient GWG was divided into underweight, normal weight, overweight, and obese with 12.5-18kg, 11.5-16kg, 7-11.5kg, and 5-9kg, respectively.

2.1 Statistical analysis

Chi-square tests (or fisher's exact tests if necessary) were used to evaluate the differences in selected characteristics between women with PIH and normotensive and between women using different types of cooking fuel. Multivariate logistic regression models were used to evaluate odds ratios (OR) and 95% confidence intervals (CI) for the association between cooking fuel and risk of PIH, as well as its clinical subtypes. Potential confounding factors included maternal age (< 25 , 25-29, 30-34, and ≥ 35), education ($< \text{College}$, $\geq \text{College}$), monthly income (< 2000 , ≥ 2000), maternal employment during pregnancy (yes or no), parity (primipara or multipara), pre-pregnancy BMI (< 18.5 , 18.5-23.9, ≥ 24), GWG (insufficient, sufficient, and excessive), smoking

during pregnancy (yes or no), folate intake during pregnancy (yes or no), multiple births (yes or no), and ventilation (yes or no) were analyzed. Additional adjustments, such as history of PIH, family history of PIH, maternal diabetes, maternal renal disease before pregnancy and progeny gender, didn't result in maternal changes observed in pregnant women and were not included in the final models. All analyses were performed using SAS, version 9.4 (SAS Institute Inc., Cary, NC, USA).

3 Results

3.1 Pregnant women with PIH showed different characteristic compared with normotensive pregnant women

568(5.43%) were diagnosed with PIH, in which 180 cases (31.69%) were GH, 377 (66.37%) were PE, and 11(1.94%) were eclampsia. Among those PE cases, 148 (39.26%) were M-PE, 229(60.74%) were S-PE. Compared to normotensive women, women with PIH were more likely to be older, less educated, less family income, higher unemployment during pregnancy, multipara, higher pre-pregnancy BMI and GWG, and have history of PIH, family history of PIH, maternal diabetes, maternal renal disease before pregnancy, less folate intake during pregnancy, multiple births, and poor cooking ventilation (Table 1). There were no significant differences in exposure to smoking during pregnancy and progeny gender between women with and without PIH.

3.2 Pregnant women using different type of cooking fuel showed different characteristic

8182(78.28%) only used gas as cooking fuel, 197(1.88%) only used electromagnetic stoves, 506 (4.84%) only used coal, and 173 (1.66%) only used biomass (Table 2). The remaining 1394 pregnant women used other fuel or multiple stoves as their cooking fuel. Compared to women who used gas, women who used coal, biomass, or electromagnetic stoves were younger, less educated, less family monthly income, unemployment during pregnancy, multipara, insufficient GWG, less normal BMI, less folate intake during pregnancy, exposing to smoking during pregnancy, multiple births, and poor cooking ventilation.

3.3 Using coal or biomass as cooking fuel was associated increased risk of PIH and PE for pregnant women

Compared to using gas for cooking, using coal (OR=2.55, 95% CI: 1.85-3.51) or biomass (OR=3.58, 95% CI: 2.29-5.60) was associated with the increased risk of PIH. Using biomass was associated with the increased risk of GH (OR=3.38, 95% CI: 1.68-6.80) and preeclampsia-eclampsia (OR=3.64, 95% CI: 2.14-6.19). Using coal was associated with the increased risk of Preeclampsia-eclampsia (OR=2.98, 95% CI: 2.06-4.31). No significant correlation were observed for electromagnetic stoves (Table 3).

Using coal (OR=2.89, 95% CI: 1.98-4.21) or biomass (OR=3.38, 95% CI: 1.95-5.84) were associated with higher risk of PE. Using biomass was associated with an increased risk of M-PE (OR=2.94, 95% CI: 1.13-7.63) and S-PE (OR=3.46, 95% CI: 1.83-6.52). Using coal was associated with an increased risk of

Table 1. Distribution of selected characteristics of the study population.

Characteristics	Normotensive(n=9884)		PIH(n=568)		P value
	n	%	n	%	
Maternal age (years)					<0.0001
<25	1578	15.97	102	17.96	
25-29	4786	48.42	198	34.86	
30-34	2630	26.61	163	28.70	
≥35	890	9.00	105	18.49	
Education					<0.0001
<College	3833	38.78	308	54.23	
≥College	5877	59.46	246	43.31	
Missing	174	1.76	14	2.46	
Family monthly income (¥)					<0.0001
<2000	2314	23.41	216	38.03	
≥2000	6634	67.12	291	51.23	
Missing	936	9.47	61	10.74	
Maternal employment during pregnancy					<0.0001
No	4761	48.17	328	57.75	
Yes	5123	51.83	240	42.25	
parity					0.0001
Primipara	7149	72.33	368	64.79	
Multipara	2735	27.67	200	35.21	
History of PIH					<0.0001
No	9722	98.36	545	95.95	
Yes	162	1.64	23	4.05	
Family history of PIH					<0.0001
No	9842	99.58	535	94.19	
Yes	42	0.42	33	5.81	
Maternal diabetes					0.0003
No	9793	99.08	554	97.54	
Yes	91	0.92	14	2.46	
Maternal renal disease before pregnancy					0.0121
No	9854	99.70	562	98.94	
Yes	30	0.30	6	1.06	
Pre-pregnancy BMI					<0.0001
<18.5	2069	20.93	74	13.03	
18.5-23.9	6510	65.86	334	58.80	
≥24	988	10.00	120	21.13	
Missing	317	3.21	40	7.04	
GWG (IOM)					<0.0001
Sufficient	3288	33.27	114	20.07	
Insufficient	1325	13.41	59	10.39	
Excessive	4876	49.33	345	60.74	
Missing	395	4.00	50	8.80	
Folate intake during pregnancy					<0.0001
No	3028	30.64	236	41.55	
Yes	6856	69.36	332	58.45	
Smoking(active and passive) during pregnancy					0.4785
No	7969	80.63	451	79.40	
Yes	1915	19.37	117	20.60	
Multiple births					<0.0001
No	9655	97.68	489	86.09	
Yes	229	2.32	79	13.91	
Progeny gender					0.1608
Male	5222	52.83	279	49.12	
Female	4632	46.86	286	50.35	
Missing	30	0.30	3	0.53	
Ventilation					<0.0001
No	2003	20.27	210	36.97	
Yes	7881	79.73	358	63.03	

Abbreviations: BMI (body mass index), GWG (gestational weight gain), IOM (Institute of Medicine), PIH (pregnancy-induced hypertension).

Table 2. Distribution of selected characteristics of the study population by cooking fuel types.

Characteristics	Gas (n=8182)		Electromagnetic (n=197)		Coal (n=506)		Biomass (n=173)		Other (n=1394)		P value
	N	%	n	%	n	%	n	%	n	%	
Maternal age (years)											<0.0001
<25	1056	12.91	58	29.44	177	34.98	69	39.88	320	22.96	
25-29	4052	49.52	87	44.16	162	32.02	61	35.26	622	44.62	
30-34	2309	28.22	42	21.32	100	19.76	26	15.03	316	22.67	
≥35	765	9.35	10	5.08	67	13.24	17	9.83	136	9.76	
Education											<0.0001
<College	2807	34.31	113	57.36	414	81.82	157	90.75	650	46.63	
≥College	5294	64.70	79	40.10	87	17.19	13	7.51	650	46.63	
Missing	81	0.99	5	2.54	5	0.99	3	1.73	94	6.74	
Family monthly income (¥)											<0.0001
<2000	1653	20.20	59	29.95	270	53.36	112	64.74	436	31.28	
≥2000	5860	71.62	98	49.75	171	33.79	38	21.97	758	54.38	
Missing	669	8.18	40	20.30	65	12.85	23	13.29	200	14.35	
Maternal employment during pregnancy											<0.0001
No	3632	44.39	125	63.45	392	77.47	144	83.24	796	57.10	
Yes	4550	55.61	72	36.55	114	22.53	29	16.76	598	42.90	
Parity											<0.0001
Primipara	6079	74.30	132	67.01	263	51.98	81	46.82	962	69.01	
Multipara	2103	25.70	65	32.99	243	48.02	92	53.18	432	30.99	
History of PIH											0.1743
No	8026	98.09	197	100.0	500	98.81	171	98.84	1373	98.49	
Yes	156	1.91	0	0.00	6	1.19	2	1.16	21	1.51	
Family history of PIH											0.1802
No	8128	99.34	196	99.49	498	98.42	171	98.84	1384	99.28	
Yes	54	0.66	1	0.51	8	1.58	2	1.16	10	0.72	
Maternal diabetes											0.4509
No	8098	98.97	195	98.98	505	99.80	171	98.84	1378	98.85	
Yes	84	1.03	2	1.02	1	0.20	2	1.16	16	1.15	
Maternal renal disease before pregnancy											0.3962
No	8155	99.67	197	100.0	502	99.21	172	99.42	1390	99.71	
Yes	27	0.33	0	0.00	4	0.79	1	0.58	4	0.29	
Pre-pregnancy BMI											<0.0001
<18.5	1694	20.70	49	24.87	97	19.17	27	15.61	276	19.80	
18.5-23.9	5457	66.70	130	65.99	319	63.04	102	58.96	836	59.97	
≥24	900	11.00	12	6.09	50	9.88	26	15.03	120	8.61	
Missing	131	1.60	6	3.05	40	7.91	18	10.40	162	11.62	
GWG (IOM)											<0.0001
Sufficient	2751	33.62	69	35.03	136	26.88	49	28.32	397	28.48	
Insufficient	953	11.65	43	21.83	126	24.90	40	23.12	222	15.93	
Excessive	4307	52.64	74	37.56	190	37.55	56	32.37	594	42.61	
Missing	171	2.09	11	5.58	54	10.67	28	16.18	181	12.98	
Folate intake during pregnancy											<0.0001
No	2207	26.91	78	39.59	278	54.94	99	57.23	607	43.54	
Yes	5980	73.09	119	60.41	228	45.06	74	42.77	787	56.46	
Smoking(active and passive) during pregnancy											<0.0001
No	6648	81.25	151	76.65	364	71.94	130	75.14	1127	80.85	
Yes	1534	18.75	46	23.35	142	28.06	43	24.86	267	19.15	
Multiple births											<0.0001
No	7994	97.70	190	96.45	472	93.28	158	91.33	1330	95.41	
Yes	188	2.30	7	3.55	34	6.72	15	8.67	64	4.59	
Progeny gender											0.6506
Male	4300	52.55	112	56.85	274	54.15	96	55.49	719	51.58	
Female	3860	47.18	84	42.64	230	45.45	76	43.93	668	47.92	
Missing	22	0.27	1	0.51	2	0.40	1	0.58	7	0.50	
Ventilation											<0.0001
No	803	9.81	69	35.03	302	59.68	135	78.03	904	64.85	
Yes	7379	90.19	128	64.97	204	40.32	38	21.97	490	35.15	

Abbreviations: BMI, body mass index; GWG, gestational weight gain; IOM, Institute of Medicine; PIH, pregnancy-induced hypertension.

Table 3. Associations of cooking fuel types with risk of PIH.

Cooking fuel types	Term (n)	PIH(n=568)		GH (n=180)		(Pre)-eclampsia (n=388)	
		No.	OR(95% CI)	No.	OR(95% CI)	No.	OR(95% CI)
Gas	7837	345	1.00(ref)	117	1.00(ref)	228	1.00(ref)
Electromagnetic	187	10	1.24(0.64-2.41)	5	1.71(0.68-4.30)	5	0.98(0.39-2.44)
Coal	433	73	2.55(1.85-3.51)	17	1.71(0.95-3.06)	56	2.98(2.06-4.31)
Biomass	137	36	3.58(2.29-5.60)	12	3.38(1.68-6.80)	24	3.64(2.14-6.19)

Note: adjusted for maternal age, education, monthly income, maternal employment during pregnancy, parity, BMI, GWG, smoking (active and passive smoking), folate intake during pregnancy, multiple births, and ventilation.

S-PE (OR=3.23, 95% CI: 2.06-5.06). No significant correlations were also observed for electromagnetic stoves (Table 4).

3.4 Using coal or biomass as cooking fuel was associated increased risk of PIH in different groups of pregnant women

In this study, whether maternal age, pre-pregnancy BMI, GWG, parity, and multiple births were effect modifiers was been analyzed (Table 5). Statistically significant interactions were

observed between cooking fuel and maternal age (Interaction $P < 0.0001$), pre-pregnancy BMI (Interaction $P < 0.0001$), GWG (Interaction $P < 0.0001$), parity (Interaction $P < 0.0001$), and multiple births (Interaction $P < 0.0001$). Among women who were younger than 30, compared to using gas for cooking, using coal (<30 , OR=3.09, 95% CI: 1.94-4.93; ≥ 30 , OR=2.10, 95% CI: 1.04-4.26), and biomass (<30 , OR=4.73, 95% CI: 2.62-8.52) were significantly associated with the risk of PIH. Among women who with normal pre-pregnancy BMI, compared to

Table 4. Associations of cooking fuel types with risk of preeclampsia.

Cooking fuel types	Term (n)	PE (n=377)		M-PE (n=148)		S-PE (n=229)	
		No.	OR(95% CI)	No.	OR(95% CI)	No.	OR(95% CI)
Gas	7837	224	1.00(ref)	99	1.00(ref)	125	1.00(ref)
Electromagnetic	187	5	1.00(0.40-2.50)	2	1.02(0.24-4.29)	3	1.01(0.31-3.28)
Coal	433	53	2.89(1.98-4.21)	14	2.21(1.17-4.17)	39	3.23(2.06-5.06)
Biomass	137	22	3.38(1.95-5.84)	6	2.94(1.13-7.63)	16	3.46(1.83-6.52)

Note: adjusted for maternal age, education, monthly income, maternal employment during pregnancy, parity, BMI, GWG, smoking (active and passive smoking), folate intake during pregnancy, multiple births, and ventilation.

Table 5. Associations between cooking fuel types and risk of PIH by maternal age, pre-pregnancy, gestational weight gain, parity, and multiple births.

Characteristics	Term (n)	Gas		Coal		Biomass			
		PIH		PIH		PIH			
		No.	OR(95% CI)	No.	OR(95% CI)	No.	OR(95% CI)		
Maternal age									
<30	4999	109	1.00(ref)	307	32	3.09(1.94-4.93)	110	20	4.73(2.62-8.52)
≥ 30	2955	119	0.78(0.45-1.34)	143	24	2.10(1.04-4.26)	39	4	0.93(0.27-3.11)
Interaction P value									<0.0001
Pre-pregnancy BMI									
18.5-23.9	5320	127	1.00(ref)	286	33	3.16(2.01-4.95)	89	13	3.31(1.67-6.57)
<18.5	1665	29	1.23(0.53-2.86)	91	6	3.05(0.96-9.70)	24	3	3.92(0.83-18.42)
≥ 24	842	58	1.40(0.65-3.00)	39	11	3.22(1.14-9.04)	21	5	4.11(1.17-14.42)
Interaction P value									<0.0001
GWG									
sufficient	2713	38	1.00(ref)	131	5	1.09(0.40-3.00)	47	2	1.66(0.37-7.39)
insufficient	936	17	1.89(0.62-5.76)	116	10	6.02(1.78-20.35)	37	3	4.88(1.01-23.58)
excessive	4140	167	1.47(0.74-2.91)	156	34	5.27(2.39-11.61)	45	11	3.71(1.37-10.04)
Interaction P value									<0.0001
Parity									
primipara	5920	159	1.00(ref)	234	29	3.20(1.99-5.16)	66	15	5.19(2.64-10.22)
multipara	2034	69	0.80(0.46-1.39)	216	27	2.14(1.09-4.22)	83	9	1.63(0.66-4.01)
Interaction P value									<0.0001
Multiple births									
No	7800	194	1.00(ref)	424	48	3.43(2.35-5.02)	138	20	3.97(2.28-6.90)
Yes	154	34	0.95(0.45-2.03)	26	8	1.01(0.35-2.93)	11	4	1.19(0.31-4.62)
Interaction P value									<0.0001

Note: Adjusted for maternal age, education, monthly income, maternal employment during pregnancy, parity, BMI, GWG, smoking (active and passive smoking), folate intake during pregnancy, multiple births, and ventilation.

using gas for cooking, using coal (normal, OR=3.16, 95% CI: 2.01-4.95; overweight, OR=3.22, 95% CI: 1.14-9.04), and biomass (normal, OR=3.31, 95% CI: 1.67-6.57; overweight, OR=4.11, 95% CI: 1.17-14.42) were also significantly associated with the risk of PIH. Also, increased risk of PIH was associated with using coal among women who had less (OR=6.02, 95% CI: 1.78-20.35) or more GWG (OR=5.27, 95% CI: 2.39-11.61), as well as insufficient (OR=4.88, 95% CI: 1.01-23.58) or excessive biomass (OR=3.71, 95% CI: 1.37-10.04). Using coal or biomass was significantly associated with the risk of PIH for primipara (coal, OR=3.20, 95% CI: 1.99-5.16; biomass, OR=5.19, 95% CI: 2.64-10.22) and single birth (coal, OR=3.43, 95% CI: 2.35-5.02; biomass, OR=3.97, 95% CI: 2.28-6.90).

4 Discussion

A few studies have estimated the association between types of cooking fuels and the risk of PIH, and the results were inconsistent. (Wylie et al., 2015; Agrawal & Yamamoto, 2015) In India, Wylie et al. (2015) conduct a study including 1369 (212 hypertension at delivery) subjects and found that compared to women cooking with gas, 14.6% of women using wood and 19.6% women using gas as their primary fuel met criteria for hypertension at delivery ($P=0.057$), but using wood fuel was not significantly associated with hypertension (adjusted prevalence ratio 0.76 [95% CI 0.49, 1.17]). They speculate that this effect may be related to the combustion by-products of biomass fuels, which are quite similar to tobacco and cigarette smoking during pregnancy was associated with a significantly reduced risk for PE (OR=0.51, 95% CI: 0.37-0.63) have been reported in meta-analysis. (Castles et al., 1999) Agrawal S et al (2015) conducted a large-scale cross-sectional nationally representative of adult women in India including 39,657 women (456 preeclampsia/eclampsia), and suggested that women living in households using biomass and solid fuels were associated with an increased risk of preeclampsia/eclampsia symptoms compared to women living in households using cleaner fuels (OR=2.21, 95% CI: 1.26-3.87), even after controlling potentially confounding factors. Consistent with the study, we also observed that using coal or biomass was associated with significantly increased risk of PE. This study suggested that biomass and coal exposure were associated with S-PE, biomass exposure also was associated with M-PE. While no study evaluated M-PE and S-PE separately in relation to solid fuels. We found that maternal age, pre-pregnancy BMI, GWG, parity, and multiple births modified the association between cooking fuels and risk of PIH. Studies reported that pre-pregnancy BMI and GWG were significantly associated with the risk of PIH (Shao et al., 2017; Stüber et al., 2015).

The combustion byproducts of solid fuel are a complex mixture of particulate and gaseous species such as particulate matter (PM), polycyclic aromatic hydrocarbons, heavy metals, carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), ozone (O₃) and so on. (Zhang & Smith, 2007) Previous studies have suggested that particulate exposure was associated with PIH (Zhu et al., 2017; Savitz et al., 2015; Lee et al., 2013; Huang et al., 2015) but inconsistent. A large retrospective cohort study from 2008 to 2010 in United States, including 206,054 women with 6074 GH, found that exposure to NO_x, PM_{2.5}, and

SO₂ during the first trimester, and NO_x, PM_{2.5}, PM₁₀, and SO₂ during gestational weeks 1-20 were associated with higher risk of GH. (Zhu et al., 2017) However, Savitz et al. (2015) conducted a study in New York City involving 268,601 women (PE 11,166, GH 5,834 and 17,000 PIH) and suggested a lack of evidence of a positive association between PM_{2.5} or NO₂ and PIH. Lee et al. (2013) reported PM_{2.5} exposure (per IQR increase) during first trimester was associated with GH (OR=1.11, 95% CI: 1.00-1.23) but not for PM₁₀ in Pittsburgh, Pennsylvania. Whereas Jin L et al (Huang et al., 2015) conducted a cohort study in China that included 8745 women (333 PIH, 127 GH and 206 PE) and observed a 10% increase for the risk of GH (OR=1.10, 95% CI: 1.00, 1.21) during the first 12 gestational weeks after PM₁₀ exposure (per 10µg/m³ increase) and S-PE during the first 20 gestational weeks was associated with PM₁₀ (OR=1.14, 95% CI: 1.01, 1.30 per 10µg/m³ increase). Pedersen et al. (2017) in Denmark conduct a study including 72,745 (PE 1880 and PIH 2430) pregnancies study subjects and found that a 10-µg/m³ increase in NO₂ exposure during first trimester was associated with increased risk of PE (OR=1.07, 95% CI: 1.01-1.14) and PIH (OR = 1.07, 95% CI: 1.01-1.13). A random-effect meta-analysis of ambient air pollution and pregnancy-induced hypertensive disorders also suggested that a 10 µg/m³ increase in NO₂ was associated with PIH (OR=1.23, 95% CI: 1.04-1.41). (Pedersen et al., 2014) Hampel et al. (2011) found negative short-term NO₂ effects on systolic blood pressure in pregnant women. A nationwide time-series analysis in China reported a short-term increase in ambient SO₂ concentration may induce deaths from hypertension disease (Wang et al., 2018).

The exact mechanisms of IAP exposure from solid fuels on PIH occurrence are not well understood. The basic pathological and physiological changes of PIH are systemic small blood vessels spasm, endothelial injury and ischemia. PM exposure is associated with systemic inflammation, endothelial dysfunction, and oxidative stress. (Becker et al., 2005; Bind et al., 2012; Ghio et al., 2000; Huang et al., 2012) PM inhalation induces inflammatory responses mediated in the lung and systemically through toll-like receptor 4/nicotinamide adenine dinucleotide phosphate (TLR4/NADPH) oxidase-dependent mechanisms, which promotes endothelial dysfunction. (Kampfrath et al., 2011) Pulmonary exposure to PM leads to activation of lung autonomic nervous system (ANS) arcs mediated, then cause ANS imbalance, leading to vasoconstriction, endothelial dysfunction, hypertension. (Chin, 2015) Routledge et al. (2006) found that SO₂ exposure can induce oxidative stress, and elevate markers of inflammation.

There were several limitations in the present study. The information on household heating source was not obtained in our study. The type of fuels of household heating was relevant to family income and education, therefore we adjusted the potential confounding in our models. The large participants of our study were came from urban areas where was concentrated heating. Whether participants in our study were the primary person in charge of food preparation, time spent in kitchen, number of meals cooked per day, and time for indoor activities were not collected in the study, which might result in exposure misclassification. However, the exposure misclassification would likely be negligible. Lack of indoor air pollution monitoring

restricted us to explore the association between the amount of air pollution and the risk of PIH.

5 Conclusions

The cohort study in Chinese population suggested that exposure to coal or biomass during pregnancy was associated with an increased risk of PIH, PE and S-PE. Biomass was also associated with an increased risk of GH and M-PE. Future studies were warranted to confirm the associations in different populations and clarify the biological mechanisms.

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