Fang, Xin-Yu, Strodl, Esben, Wu, Chuan-An, Liu, Li, Yin, Xiao-Na, Wen, Guo-Min, Sun, Dengli, Xian, Dan-Xia, Jiang, Hui, Jiang, Jin, Jin, Yu, & Chen, Wei-Qing
(2019)
Maternal cooking during pregnancy may increase hyperactive behaviors among children aged at around 3 years old.
Indoor Air, *30*(1), pp. 126-136.

https://doi.org/10.1111/ina.12614

Title page

Maternal Cooking during Pregnancy May Increase Hyperactive Behaviors among Children Aged at around 3 Years Old

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Maternal Cooking during Pregnancy May Increase Hyperactive Behaviors among Children Aged around 3 Years Old

Abstract

Cooking is one of the main sources of indoor air pollution in China. Given emerging evidence of a link between air pollutants and neurodevelopmental delays, we examined whether maternal experiences with cooking during gestation might increase their child's hyperactivity at 3 years of age. The participants involved 45518 mothers of children who were newly enrolled at kindergarten in the Longhua District of Shenzhen from 2015 to 2017. The results show that maternal exposure to cooking fumes during pregnancy was related to an increased risk of their off-spring having hyperactivity behaviors at the age of 3 years. Compared with pregnant mothers who never cooked, pregnant mothers who cooked sometimes, often or always had children who showed a significantly higher hyperactivity risk. Households using cooking fuels such as coal, gas during the mothers' pregnancy, exhibited more hyperactivity behaviors in the young child when compared to those using electricity for cooking. In addition, poor ventilation during cooking, while mothers were pregnant, was found to be a significant risk factor for clinical levels of the offspring's hyperactive behaviors. Furthermore, the positive association with maternal cooking during pregnancy and their offsprings' hyperactivity was relatively consistent across strata defined by social class, education, and other covariates.

Keys words: cooking, hyperactive behaviors, prenatal, pregnant woman, child, preschool

Practical Implications

There is an obvious need to raise the public's awareness to the harmful effect of maternal prenatal exposure to cooking fumes on child hyperactivity and to elucidate the factors which affect cooking emissions in order to guide the development and implementation of effective interventions. These findings support the implication that reducing cooking emission through using clean fuels and improving ventilation conditions in households of women who cook during pregnancy can decrease the prevalence of child hyperactive behaviors.

1. Introduction

Hyperactivity is one of the primary clinical symptoms of attention deficit hyperactivity disorder (ADHD)[1]. In turn, ADHD is one of the most prevalent childhood neurobehavioral disorders[1], and can cause significant impairment in the affected individuals' performance in social, educational, or work environments, as well as placing long-term economic burdens on the family and country[2-5]. The exact causes of hyperactivity have not yet been fully elucidated and so there is a need to further explore risk factors for the presence of hyperactive behaviors in children.

There is emerging evidence that air pollutants may impair children's neurodevelopment[6, 7]. Given that pregnant women are susceptible to indoor environmental hazards[8], and given that the brain cortex maturation is intensive in the utero life, fetal brain development may be particularly vulnerable to exposure to environmental pollutants[9]. A series of prior epidemiological studies have already indicated a link between air pollution exposure prenatally and the increased risk of child behavior problems[10-16]. For example, prenatal exposure to polycyclic aromatic hydrocarbons(PAH) was found to be associated with adverse cognitive outcomes around age 5 years in the birth cohort studies in both New York and Krakow [10, 11], and with behavioral problems at ages 6 to 7 years[12]. Although the epidemiological evidence mentioned above have focused on outdoor air pollution, these findings also raise concerns about similar effects from indoor air pollution.

According to the Ministry of Health of China, although Chinas economy has grown rapidly in recent decades, many people living in rural areas still use solid fuels (coal, wood) for daily cooking and heating purposes[17]. Moreover, unlike the single method of cooking meals typical in Western culture, Chinese people tend to cook at home by multiple means simultaneously such as stir-frying, deep-frying and, pan-frying, which produces an extensively larger amount of lampblack[18]. Lampblack includes large quantities of harmful substances, such

as particulate matter, carbon monoxide, nitrogen oxides, PAHs, acids, alcohols, and aldehyde[19-22]. Compared with inside rooms when no cooking has occurred, cooking increases the average concentration of particles in the kitchen by 20-40 times and the living room by 10 times[23]. Therefore, cooking is an important potential source of indoor air pollution in China, particularly for Chinese women who typically do the family cooking. This is potentially problematic for young Chinese children given the finding from a small birth-cohort study indicating that early life exposure to air pollution from indoor gas appliances was inversely associated with cognitive function and increased risk of ADHD symptoms[24]. Similarly, a prospective birth cohort study conducted on a bigger Spanish population (1887 mother-child pairs) also reported that the presence of a gas cooker was associated with slower mental development of young children[25]. However, no study to date has examined the impact of experiences with cooking during pregnancy on subsequent child hyperactivity. Therefore, the aim of the current study was to assess whether maternal exposure during pregnancy was associated with an increased risk of hyperactivity in the mother's child when the child was aged 3 years old.

2. Methods

2.1 Study population

The current study was based on the baseline survey of a large population-based cohort study initially recruited in the autumn of 2015 from 171 kindergartens in the Longhua District of Shenzhen, a coastal city located in the southern region of Mainland China. In brief, the Longhua Child Cohort Study (LCCS) is an on-going prospective cohort study which was designed to evaluate the impact of family and school environment on children's mental and behavioral problems. Detailed information about the research procedures of the LCCS have been described elsewhere[26]. This analysis was grounded on baseline data on the mother's recall of cooking exposure during pregnancy and their observations of their child's hyperactive behaviors when children were in their first year of preschool. The data was collected during October 2015 to

October 2017. Children of mothers who did not answer questions on cooking exposure or complete information on hyperactive behaviors were not included (n=526) resulting in 45518 mother-child pairs being included in the analysis. Participants signed informed consent forms after having the study explained to them. The study was approved by the Ethic Committee of School of Public Health of Sun Yat-sen University.

2.2 Data collection procedures

The parents were given a questionnaire and asked to complete it under the guidance of a trained health-care assistant. The demographic questions included the number of people residing together; participant's home address at birth, maternal and paternal age at child birth; parental education; family income per month; migrant status; marital status; maternal obstetric history, birth weight, premature birth and child age and sex; delivery way (eutocia, caesarean); feeding pattern (breast feeding, mixed feeding, artificial feeding); and consumption of multivitamins, folic acid, calcium use, and alcohol; as well as engagement in active and passive cigarette smoking. Also, we collected the information about average daily sleep duration for children and the frequencies of parent-child interactive activities for different time periods: before their child was 1 year old and when their child was 1 to 3 years old. More details about parent-child interactive activities can be seen in our pervious study[27].

In addition, average outdoor $PM_{2.5}$ and NO_2 concentrations at each participant's home address at birth were evaluated for the pregnancy period by land-use regression models[28] .

2.3 Exposure assessment of maternal cooking

Maternal cooking status during pregnancy was measured with the following questions: when you were pregnant with your child who is now attending preschool 1) did you ever cook (yes vs. no); 2) what was the frequency of cooking (never, occasionally, sometimes, often, always); 3) what type of cooking fuels were used (electricity, nature gas, liquefied petroleum gas, coal and others); 4) what was the condition of the kitchen ventilation when you cooked (good, fairly

good, poor); and 5) what amount of cooking fumes did you experience when you cooked (little, a lot of). We defined those who cooked at least once per month during pregnancy as "occasionally cooking", those who cooked at least one time every two weeks during pregnancy as "sometimes cooking" and considered those who cooking at least once per week during pregnancy as "often cooking" as well as those who cooking at least once every day during pregnancy as "always cooking". For the kitchen ventilation condition, we defined those who always used an extractor fan when cooking as "good ventilation" and those who sometimes used an extractor fan or who always opened a door and windows when cooking as "fairly good" and those who never used an extractor fan or sometimes opened a door and windows when cooking as "poor ventilation" .

2.4 Measurement of hyperactive behaviors

The Conners' Hyperactivity Index (HI), a subscale of the Conners' Parent Rating Scale-Revised (CPRS-48), was used to measure the children's hyperactive behaviors in our study. The scale is widely validated and utilized across a range of international studies to assess hyperactive behaviors in children aged between 3-17 years old[29]. This tool has previously been translated into Chinese and demonstrated to have good reliability and validity[30]. The HI measure is comprised of 10 items, with the scores from the items summed and then divided by 10 to get a mean score that ranges from 0 to 3. A higher score indicates a higher level of hyperactivity. In our study, the Cronbach's α coefficient for the HI was 0.83. In addition to this continuous measure of hyperactivity, the HI was also treated as a dichotomous measure by using the 90th percent HI score for the child's age and gender as the cut-off for establishing the presence of hyperactive behaviors[30, 31].

2.5 Statistical analysis

Continuous variables were described in terms of means and standardized deviations, while categorical variables were described as frequencies and proportions. T-tests or chi-square tests

were used where appropriate for comparison between groups. Unconditional binary logistic regression models were used to examine the association between cooking during pregnancy and the dichotomous measure of the presence of child hyperactive behaviors. In addition, multivariate liner regression models were utilized to assess the association between exposure to cooking during pregnancy and the continuous measure of child hyperactive behaviors. Since some HI scores contained "0" values, we added the value of "1" to the HI score and preformed a natural logarithmic transformation to reduce the skewness of the data for multiple linear regression model.

Covariates included child's sex and age, maternal and paternal education, maternal and paternal age at the time of the birth, family income, marital status, migrant status, birth weight, premature birth, parity, delivery way, feeding pattern, maternal active and passive smoking during pregnancy, gestation alcohol consumption, multivitamins, folic acid, or calcium supplementation during pregnancy, average daily sleep duration for children and frequencies of parent-child interactive activities at 0-1 and 1-3 years and number of persons in the house. All the covariates significantly related to the outcome ($p < 0.20$) were included in the multivariate model, and they were retained only if they modified the coefficient of the cooking variable by more than 10%[32]. The final multivariate model was adjusted for child sex and age, migrant status, maternal and paternal age at birth, maternal and paternal education, family income, marital status, parity, multivitamins supplementation during pregnancy, passive smoking during pregnancy, feeding pattern, premature birth, average daily sleep duration for children and frequencies of parent-child interactive activities at 0-1 and 1-3 years .

We examined the robustness of results over various strata of potential confounding variables. We also stratified by supplementation of antioxidant nutrients (feeding pattern, multivitamins, folic acid, or calcium consumption during pregnancy), which were possible modifiers of air pollution effects as reported in the literature[33]. Given outdoor air pollution may

also associated with behavior problems, we conducted a subgroup analysis of those mothers who were living in Shenzhen during pregnancy to evaluate the influence of adjusting for $PM_{2.5}$ and NO_2.

The statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) and Statistics Analysis System (SAS, version 9.3, SAS Institute Inc., Cary, NC, USA). All of the p-values were two-sided. Type I errors were set at $p<.05$.

3 Results

A total of 45518 mother-child dyads were enrolled in the study. The mean maternal age at child birth was 27.43 (SD=4.05) years old. There were no statistically significant differences in family income and maternal education level between mothers who cooked and those who did not. Mothers with cooking exposure during pregnancy disclosed lower levels of passive and active smoking during gestation. They also reported lower consumption of vitamins, but their intake of folic acid and calcium and the proportion of breast-feeding were similar to mothers who did not cook during gestation. Finally, households where mothers who cooked during pregnancy had fewer residents in the household.

The mother-related Conners' HI scores ranged from 0 to 3, and 13.3% (6053/45518) of the participants were over the threshold of a high probability of hyperactive behaviors according to the standard cut-off value (i.e. using the 90th percent HI score). Of the investigated children, 54.4% were boys and the mean age was 3.45 (SD = 0.40) years old (see Table1).

Insert Table 1 about here

As shown in Table 2, in this sample, 45.3 (20616/45518) percent of mothers reported cooking at home during the pregnancy. Of these, most cooked using electricity (n = 14212), while the rest used natural gas or liquefied petroleum gas to cook. Of those who did not use light fuels, most used coal for cooking. The presence of prenatal cooking exposure was

significantly associated with the presence of hyperactivity behaviors in the mother's young children both in the univariate model (OR = 1.15, 95% CI = 1.09-1.21, $p < 0.001$; β = 0.015, 95% CI = 0.011-0.020, $p < 0.001$), and in the adjusted model (OR = 1.17, 95% CI = 1.10-1.24, $p < 0.001$; β = 0.021, 95% CI = 0.015-0.024, $p < 0.001$). Compared with pregnant mothers who never cooked, those who cooked were sometimes (OR = 1.32, 95% CI = 1.21-1.44, $p < 0.001$; β = 0.030, 95% CI = 0.023-0.038, $p < 0.001$) or often (OR = 1.92, 95% CI = 1.55-2.38, $p < 0.001$; β = 0.042, 95% CI = 0.033-0.045, $p < 0.05$) and always (OR = 2.40, 95% CI = 1.88-3.05, $p < 0.001$; β = 0.131, 95% CI = 0.105–0.157, $p < 0.001$) likely to show a significantly higher risk of hyperactivity after adjusting for the covariates. Likewise, those who reported being exposed to a lot of cooking fumes during pregnancy had an increased risk of offspring's hyperactive behaviors compared to those who reported little exposure to cooking fumes (OR = 1.83, 95% CI = 1.38-2.44, $p < 0.001$; β = 0.072, 95% CI = 0.041-0.102, $p < 0.001$). In addition, an increased risk of hyperactive behaviors in the child was found when mothers had used coal (OR =2.16, 95% CI = 1.59-2.99, $p < 0.001$; β = 0.104, 95% CI = 0.071-0.138, $p < 0.001$) and liquefied petroleum gas (OR = 1.75, 95% CI = 1.46-2.10, $p < 0.001$; β = 0.075, 95% CI = 0.058-0.092, $p < 0.001$) or natural gas (OR = 1.69, 95% CI = 1.51-1.90, $p < 0.001$; β = 0.075, 95% CI = 0.065-0.085, $p < 0.001$) in cooking, compared to those who had used electricity to cook. Furthermore, poor ventilation in the kitchen was found to be a significant risk factor for the presence of hyperactive behaviors in the children in both the univariate and adjusted models. This relationship was further demonstrated by a stratified analysis of cooking fumes and ventilation condition (Table 3). However, we did not observe a significant interaction effect ($p = 0.737$).

Insert Table 2 and 3 about here

When the analyses were stratified by the covariates (Table 4), we found that the negative effect of maternal cooking during pregnancy was fairly homogeneous in most subcategories and that there was little evidence for interactions between these variables and the cooking condition (test for interaction $p > 0.1$) with the except for passive smoking during pregnancy ($p < 0.01$). The greatest risks for the presence of childhood hyperactive behaviors, that were related to maternal cooking during pregnancy, were found in a) families with the lowest income, b) mothers who were migrants, c) mothers with primary educational level, d) households where more than 4 persons resided, and e) households were at least one person smoked. The effect of maternal cooking during pregnancy on child's hyperactive behaviors was somewhat stronger in mothers who did not consume folic acid or calcium during gestation. When the analyses were preformed separately for children who were born in Shenzhen with and without adjusting for outdoor $PM_{2.5}$ and NO_2 concentration, we observed very similar results (Table 5).

Insert Table 4 ,5 about here

4 Discussion

This study examined the association between maternal exposure to cooking fumes during pregnancy and the offspring's hyperactive behaviors at around 3 years old using baseline data of LCCS that include 45518 participants in Southern China. Our finding supported the conclusion that the presence of cooking experience at home during pregnancy was associated with the presence of hyperactivity behaviors in the offspring. These, associations were relatively consistent across social and educational categories. Moreover, we found that the higher the frequency of cooking during pregnancy, the greater the risk of children's hyperactive behaviors. Furthermore, compared with pregnant women who used electricity for cooking during pregnancy, those who used natural gas or LPG gas or coal were likely to have a

significantly increased risk of hyperactive behaviors. In addition, having a kitchen with good ventilation was protective to the development of hyperactive behaviors.

Previous research on the associations between cooking and health have largely focused on respiratory illness, cardiovascular diseases and adverse birth outcome[34], with only a few studies examining the effects on neurobehavioral development. For example, two studies in Spain indicated that a mother's exposure to gas cooking during pregnancy was associated with harmful effects on their child's neurobehavioral development[25, 35]. In line with these two studies, our study showed that maternal cooking during pregnancy was associated with a higher risk of the offspring's level of hyperactivity, with a dose-response relationship between the cooking frequency and the risk of hyperactive behaviors. All these findings support a deleterious effect of maternal cooking during pregnancy with offspring's neurobehavioral development.

It is well known that cooking emissions are influenced by many factors, such as cooking duration, fuel types and ventilation[36]. Recently, a prospective birth cohort study reported that exposure to cooking with gas during pregnancy was related to a poor mental development compared to cooking with electricity (β = -2.5, 95% CI = -4.0 ~ -0.9) and that the effect was further strengthened when combined with poor ventilation (β = -3.6, 95% CI = -6.0 ~ -1.1)[25]. Similarly, our study also found an increased risk of the presence of hyperactive behaviors in the children of mothers who had used coal and liquefied petroleum gas or natural gas in cooking during pregnancy compared with those who cooked with electricity. In addition, our study presented evidence that having a good ventilation during maternal cooking can effectively reduce the hazards of cooking and was protective against the development of hyperactive behaviors in the offspring. Though no other studies have observed the relationship between maternal cooking during pregnancy and childhood neurobehavior development, cross-sectional epidemiological studies have shown a higher risk of prevalent cases of childhood asthma in

homes with gas stoves compared with homes with electric stoves[37-39]. Blair, and colleagues found the use of wood cooking fuel increased the risk of preeclampsia compared to gas fuel[40]. A nationwide population-based study in Bangladesh reported that the risk of the development of child acute respiratory infection and low birth weight were significant increased while cooking inside the house and using indoor solid fuels[41]. A review which focused on lung cancer in Xuanwei indicated that the installation of a chimney in homes resulted in a substantial reduction in lung cancer incidence and mortality[42]. Analogously, a nested case-control study found that always using a fume extractor during cooking can reduce the risk of cervical intraepithelial neoplasm in women in China[43]. Overall, these findings suggest that when exposure to cooking fumes is unavoidable, the use of clean fuels and improved ventilation are necessary and effectivity ways to reduce the hazards upon health.

In addition to above mentioned analyses, we also evaluated the robustness of cooking during pregnancy upon children's hyperactivity by stratification analysis, and the negative effects of cooking during pregnancy were demonstrated to be fairly consistent across most subcategories. The replication of an association of cooking with neuro-development in different subgroups strengthens the evidence for a causal association, although similar confounding structures cannot be excluded as explanation.

Although the mechanisms by which maternal cooking might affect the developing brain of fetus has not yet been fully elucidated, some studies have already provided possible explanations. During the cooking process, the fumes emitted contain particulate matter (PM), polycyclic aromatic hydrocarbon (PAH), volatile organic compounds (VOCs), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and other gaseous compounds[44-46]. Moreover, these pollutants which the mothers potentially inhale may translocate from the respiratory tract into the systemic circulation and cross the placenta to gain access to the fetal circulation[47]. These substances promote chronic neuro-inflammation, oxidative stress,

microglia activation, white matter abnormalities and endocrine disruption, and subsequent damage the central nervous system[48]. Precursors of the central nervous system originate early in embryogenesis and specific areas of the brain start to develop within the first month of pregnancy[49]. Normal brain development requires careful coordination of a number of vital processes covering proliferation, differentiation, migration, synaptogenesis, apoptosis, and myelination[49]. Interruption of any of these processes can lead to functional developmental abnormalities[49]. Different pollutants may exert their neurotoxic effects via a variety of different pathways[50]. For instance, CO readily diffuses across the placenta and binds to fetal hemoglobin after maternal exposure to CO and formation of COHb[51, 52]. PAHs can arouse DNA damage resulting in activation of apoptotic pathways[53-55]. Apoptosis has been shown to be a mechanism of physiologic cell death in cerebellar granule neurons in vivo during the first 2 weeks of postnatal development[56] as well as binding to receptors for placental growth factors leading to decreased exchange of oxygen and nutrients[57]. Although little is known about the direct neurotoxic effects of NO_2, it is speculated that it may lead to lipid per-oxidation in the brain or interference with dopamine biosynthesis[24]. In addition, the effects on childhood hyperactivity found between cooking with different types of fuel during pregnancy may be due to the unequal release of harmful substances. Several studies reported that cooking with electricity and natural gas released less particular matter (PM) and PAHs than when cooking with coal and biomass [58-60]. A Spanish cohort study also found that more NO_2 was emitted by butane and propane gas than by natural gas[61]. Further, good ventilation may have a similar mechanism for reducing the risk of hyperactivity in children. For instance, a recent experimental study demonstrated that the wind speed of the kitchen ventilator directly affected the level of PM concentration during the cooking process, and that the concentration of PM could be decreased by over 65 percent at high wind speed when compared to medium wind speed[62]. These results provide some support

for our findings, but more research is needed to verify these findings and to identify more clearly and comprehensively the potential mechanisms.

Several limitations should be considered in this study. This study used the baseline data of the LCCS. Therefore, the measures of maternal cooking experiences during pregnancy were based upon the mothers' recall of these experiences from three years earlier and so there is a risk of recall bias. We therefore need to be cautious about suggesting a causal relationship between cooking exposure during pregnancy and the subsequent presence of hyperactive behaviors in the mother's child when the child was around 3 years of age. In addition, the assessment of cooking exposure in the questionnaire was limited. We did not collect information in different trimesters of pregnancy, the time spent cooking, and the methods (e.g. frying, roasting, grilling, boiling and broiling) or ingredients (e.g. meat, vegetables) used in cooking. We also had no information on the household's kitchen design (separated or open plan) and we had no measure of the levels of NO_2, polycyclic aromatic hydrocarbons, or other gas-cooking-related pollutants both in the kitchen and in the living room. Better measurement of these factors that may characterize the level of exposure to cooking related fumes, as well as the measurement of the air pollutants will be important for future studies. In addition, given that the exposure assessment was limited to prenatal period only, the study lacked information about postnatal and infanthood exposure to air pollutants or other pollutants (e.g. lead or mercury in food). Thus, it is hard to determine how the timing of exposure (prenatal versus postnatal versus infanthood) might affect the associations identified in this study. As such conclusions can not be extended to further time periods of infant/child exposure to cooking fumes, although we expect a larger effect during the development of the child in utero, when critical brain growth occurs. Another limitation of our study is that we did not have exact outdoor air pollution data for children's birth addresses that were not in Shenzhen City (36.9% of the children were not born in Shenzhen). However, when we analyzed the smaller sample of

participants with available outdoor air pollution data, the association between prenatal cooking exposure and child hyperactivity was quite similar before and after adjusting for $PM_{2.5}$ and NO_2 concentrations. Finally, while we controlled for the potential confounding effects of a wide range of demographic factors, gestation risk factors, life-style habits, and cognitively stimulating activities at age 0-3 years old, there may still be a range of other potential confounding risk factors for behavior problems that should be measured in future studies (such as family history of ADHD and home environmental indicators).

5 Conclusions

Taken together, our results suggest that cooking during pregnancy is associated with an increased risk of hyperactive behaviors in children at around 3 years of age. Moreover, these risks were higher when the mothers cooked frequently, or when the households used gas or solid fuels for cooking, or the kitchen was poorly ventilated. If our findings are replicated in future longitudinal and interventional studies, then they will provide crucial evidence to support a relatively simple, low-cost, and sustainable public health intervention to decrease the rates of hyperactive behaviors in children. Such an intervention could have a significant positive impact on reducing the social, emotional, and economic burden on individuals, families, and societies affected by hyperactive behaviors.

Acknowledgments

This study was conducted as part of Longhua Child Cohort Study, which is supported by the Shenzhen Longhua District Government of China. The School of Public Health in Sun Yat-sen University undertook this study. The authors would like to thank the staffs in Longhua Maternal and Child Health Care Center, especially Chuan-An Wu, Xiao-Na Yin, Guo-Ming Wen, Deng-Li Sun, and Dan-Xia Xian, who offered much help during the field investigation. We are also grateful to all families who took part in this study.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Bogduk N . Diagnostic and Statistical Manual of Mental Disorders[M]. *Springer Berlin Heidelberg*, 2013.

2. Sihvola E, Rose RJ, Dick DM, et al. Prospective relationships of ADHD symptoms with developing substance use in a population-derived sample. *Psychological Medicine*. 2011;41:2615-23.

3. Plessen KJ, Bansal R, Zhu H, et al. Hippocampus and amygdala morphology in attention-deficit/hyperactivity disorder. *Arch Gen Psychiatry*. 2006;63:795.

4. Scholtens S, Rydell AM, Yangwallentin F. ADHD symptoms, academic achievement, self-perception of academic competence and future orientation: a longitudinal study. *Scandinavian Journal of Psychology*. 2013;54:205-12.

5. Fletcher JM. The effects of childhood ADHD on adult labor market outcomes. *Health Economics*. 2014;23:159-81.

6. Perera FP, Rauh V, Whyatt RM, et al. Effect of prenatal exposure to airborne polycyclic aromatic hydrocarbons on neurodevelopment in the first 3 years of life among inner-city children. *Environ Health Perspect*. 2006;114:1287-92.

7. Suglia SF, Gryparis A, Wright RO, et al. Association of black carbon with cognition among children in a prospective birth cohort study. *Am J Epidemiol*. 2008;167:280-6.

8. Chang J, Streitman D. Physiologic adaptations to pregnancy. *Neurologic Clinics*. 2012;30:781-9.

9. Grandjean P, Landrigan PJ. Developmental neurotoxicity of industrial chemicals. *Lancet*. 2006;368:2167-78.

10. Perera FP, Li Z, Whyatt R, et al. Prenatal airborne polycyclic aromatic hydrocarbon exposure and child IQ at age 5 years. *Pediatrics*. 2009;124:e195-202.

11. Edwards SC, Jedrychowski W, Butscher M, et al. Prenatal exposure to airborne polycyclic aromatic hydrocarbons and children's intelligence at 5 years of age in a prospective cohort study in Poland. *Environ Health Perspect*. 2010;118:1326-31.

12. Perera FP, Tang D, Wang S, et al. Prenatal polycyclic aromatic hydrocarbon (PAH) exposure and child behavior at age 6-7 years. *Environ Health Perspect*. 2012;120:921-6.

13. Newman NC, Ryan P, Lemasters G, et al. Traffic-Related Air Pollution Exposure in the First Year of Life and Behavioral Scores at 7 Years of Age. *Environmental Health Perspectives*. 2013;121:731-6.

14. Perera FP, Hsin-Wen C, Deliang T, et al. Early-life exposure to polycyclic aromatic hydrocarbons and ADHD behavior problems. *Plos One*. 2014;9:e111670.

15. Shabana S, Madhuchanda B, Manas Ranjan R, et al. Attention-deficit hyperactivity disorder in children chronically exposed to high level of vehicular pollution. *European Journal of Pediatrics*. 2011;170:923-9.

16. Min JY, Min KB. Exposure to ambient PM10 and NO2 and the incidence of attention-deficit hyperactivity disorder in childhood. *Environment international*. 2017;99:221.
17. Zhang Y, Mo J, Weschler CJ. Reducing Health Risks from Indoor Exposures in Rapidly Developing Urban China. *Environmental Health Perspectives*. 2013;121:751-5.
18. Marion H, Marzia S, Giovanni V, et al. Respiratory health and indoor air pollutants based on quantitative exposure assessments. *European Respiratory Journal*. 2012;40:1033.
19. Fullana A, Carbonell-Barrachina AA, Sidhu S. Comparison of volatile aldehydes present in the cooking fumes of extra virgin olive, olive, and canola oils. *Journal of Agricultural & Food Chemistry*. 2004;52:5207-14.
20. Fullana A, Carbonellbarrachina AA, Sidhu S. Volatile aldehyde emissions from heated cooking oils. *Journal of the Science of Food & Agriculture*. 2010;84:2015-21.
21. Guillén MD, Cabo N, And MLI, et al. Study of both Sunflower Oil and Its Headspace throughout the Oxidation Process. Occurrence in the Headspace of Toxic Oxygenated Aldehydes. *Journal of Agricultural & Food Chemistry*. 2005;53:1093-101.
22. Organization GWH, Committee WGAbtGR. WHO Guidelines for Indoor Air Quality: Dampness and Mould. *Who Guidelines for Indoor Air Quality Dampness & Mould*. 2011.
23. Wan MP, Wu CL, To GNS, et al. Ultrafine particles, and PM 2.5 generated from cooking in homes. *Atmospheric Environment*. 2011;45:6141-8.
24. Eva M, Jordi J, Maties T, et al. Association of early-life exposure to household gas appliances and indoor nitrogen dioxide with cognition and attention behavior in preschoolers. *American Journal of Epidemiology*. 2009;169:1327.
25. Vrijheid M, Martinez D, Aguilera I, et al. Indoor air pollution from gas cooking and infant neurodevelopment. *Epidemiology*. 2012;23:23-32.
26. Ruan ZL, Liu L, Strodl E, et al. Antenatal Training with Music and Maternal Talk Concurrently May Reduce Autistic-Like Behaviors at around 3 Years of Age. *Front Psychiatry*. 2017;8:305-.
27. He GH, Liu L, Strodl E, et al. Parental Type D Personality and Children's Hyperactive Behaviors: The Mediating Role of Parent(-)Child Interactive Activities. *International journal of environmental research and public health*. 2019;16.
28. Beelen R, Hoek G, Vienneau D, et al. Development of NO2 and NOx land use regression models for estimating air pollution exposure in 36 study areas in Europe - The ESCAPE project. *Atmospheric Environment*. 2013;72:10-23.
29. Goyette CH, Conners CK, Ulrich RF. Normative data on Revised Conners Parent and Teacher Rating Scales. *Journal of Abnormal Child Psychology*. 1978;6:221-36.
30. Su LY, Li XR, Huang CX, Luo XR, Zhang JS. Norms of the Conners Parent Symptom Questionnaire in Chinese Urban Children. *Chinese Journal of Clinical Psychology*. 2001;9:241-3.

31. Conners CK, Sitarenios G, Parker JD, et al. The revised Conners' Parent Rating Scale (CPRS-R): factor structure, reliability, and criterion validity. *J Abnorm Child Psychol*. 1998;26:257-68.
32. Greenland S. Modeling and variable selection in epidemiologic analysis. *American journal of public health*. 1989;79:340-9.
33. Romieu I, Castro-Giner F, Kunzli N, et al. Air pollution, oxidative stress and dietary supplementation: a review. *The European respiratory journal*. 2008;31:179-97.
34. Fullerton DG, Bruce N, Gordon SB. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. 2008;102:843-51.
35. Morales E, Julvez J, Torrent M, et al. Association of early-life exposure to household gas appliances and indoor nitrogen dioxide with cognition and attention behavior in preschoolers. *Am J Epidemiol*. 2009;169:1327-36.
36. Kang K, Kim H, Kim DD, et al. Characteristics of cooking-generated PM10 and PM2.5 in residential buildings with different cooking and ventilation types. *The Science of the total environment*. 2019;668:56-66.
37. Dekker C, Dales R, Bartlett S, et al. Childhood asthma and the indoor environment. *Chest*. 1991;100:922-6.
38. Maier WC, Arrighi HM, Morray B, et al. Indoor risk factors for asthma and wheezing among Seattle school children. *Environ Health Perspect*. 1997;105:208-14.
39. Lanphear BP, Aligne CA, Auinger P, et al. Residential exposures associated with asthma in US children. *Pediatrics*. 2001;107:505-11.
40. Wylie BJ, Singh MP, Coull BA, et al. Association between wood cooking fuel and maternal hypertension at delivery in central East India. *Hypertension in pregnancy*. 2015;34:355-68.
41. Khan MN, CZ BN, Mofizul Islam M, et al. Household air pollution from cooking and risk of adverse health and birth outcomes in Bangladesh: a nationwide population-based study. *Environmental health : a global access science source*. 2017;16:57.
42. Seow WJ, Hu W, Vermeulen R, et al. Household air pollution and lung cancer in China: a review of studies in Xuanwei. *Chin J Cancer*. 2014;33:471-5.
43. Wu MT, Lee LH, Ho CK, et al. Environmental exposure to cooking oil fumes and cervical intraepithelial neoplasm. *Environmental research*. 2004;94:25-32.
44. Wang L, Xiang Z, Stevanovic S, et al. Role of Chinese cooking emissions on ambient air quality and human health. *Science of the Total Environment*. 2017;589:173-81.
45. Ke Y, Huang L, Xia J, et al. Comparative study of oxidative stress biomarkers in urine of cooks exposed to three types of cooking-related particles. *Toxicology Letters*. 2016;255:36-42.
46. Peng CY, Lan CH, Lin PC, et al. Effects of cooking method, cooking oil, and food type on aldehyde emissions in cooking oil fumes. *Journal of Hazardous Materials*. 2017;324:160.

47. van den Hooven EH, Pierik FH, de Kluizenaar Y, et al. Air pollution exposure and markers of placental growth and function: the generation R study. *Environ Health Perspect*. 2012;120:1753-9.
48. Block ML, Calderon-Garciduenas L. Air pollution: mechanisms of neuroinflammation and CNS disease. *Trends Neurosci*. 2009;32:506-16.
49. Rice D, Barone S, Jr. Critical periods of vulnerability for the developing nervous system: evidence from humans and animal models. *Environ Health Perspect*. 2000;108 Suppl 3:511-33.
50. Block ML, Elder A, Auten RL, et al. The outdoor air pollution and brain health workshop. *Neurotoxicology*. 2012;33:972-84.
51. Bissonnette JM, Wickham WK. Placental diffusing capacity for carbon monoxide in unanesthetized guinea pigs. *Respiration physiology*. 1977;31:161-8.
52. McGregor HP, Westcott K, Walker DW. The effect of prenatal exposure to carbon monoxide on breathing and growth of the newborn guinea pig. *Pediatric research*. 1998;43:126-31.
53. Meyn MS. Ataxia-telangiectasia and cellular responses to DNA damage. *Cancer Research*. 1996;55:5991-6001.
54. Nicol CJ, Harrison ML, Laposa RR, et al. A teratologic suppressor role for p53 in benzo[a]pyrene-treated transgenic p53-deficient mice. *Nature genetics*. 1995;10:181-7.
55. Wood KA, Youle RJ. The role of free radicals and p53 in neuron apoptosis in vivo. *The Journal of neuroscience : the official journal of the Society for Neuroscience*. 1995;15:5851-7.
56. Wood KA, Dipasquale B, Youle RJ. In situ labeling of granule cells for apoptosis-associated DNA fragmentation reveals different mechanisms of cell loss in developing cerebellum. *Neuron*. 1993;11:621-32.
57. Binkova RJSB, Dejmek J, Solansky I. 9. THE IMPACT OF POLYCYCLIC AROMATIC HYDROCARBONS AND FINE PARTICLES ON PREGNANCY OUTCOME. *Environmental Health Perspectives*. 2000;108:1159-64.
58. Amouei Torkmahalleh M, Gorjinezhad S, Unluevcek HS, et al. Review of factors impacting emission/concentration of cooking generated particulate matter. *The Science of the total environment*. 2017;586:1046-56.
59. Park SU, Kim JG, Jeong MJ, et al. Source identification of atmospheric polycyclic aromatic hydrocarbons in industrial complex using diagnostic ratios and multivariate factor analysis. *Archives of environmental contamination and toxicology*. 2011;60:576-89.
60. Shen G, Tao S, Chen Y, et al. Emission characteristics for polycyclic aromatic hydrocarbons from solid fuels burned in domestic stoves in rural China. *Environmental science & technology*. 2013;47:14485-94.
61. Esplugues A, Ballester F, Estarlich M, et al. Indoor and outdoor concentrations and determinants of NO2 in a cohort of 1-year-old children in Valencia, Spain. *Indoor air*. 2010;20:213-23.

62. Lu F, Shen B, Yuan P, et al. The emission of PM2.5 in respiratory zone from Chinese family cooking and its health effect. *The Science of the total environment*. 2019;654:671-7.

Table1. Summary measures of covariates by prenatal cooking and hyperactive behaviors

Covariates	Cooking(N=45518)			Hyperactive behaviors(N=45518)		
	Yes (n=20616)	No (n=24902)	P value	Yes (n=6053)	No (n=39465)	P value
Child sex, n (%)			0.594			0.210
Girl	9380(45.5)	13497(54.2)		2809(46.4)	17957(45.5)	
Boy	11236(54.5)	11405(45.8)		3244(53.6)	21508(54.5)	
Child age; mean (SD)	3.45(0.40)	3.46(0.39)	0.048	3.40(0.39)	3.46(0.40)	<0.001
Birth weight; mean (g, SD)	3254(449)	3255(443)	0.758	3235(444)	3257(446)	<0.001
Migrant, n (%)			0.602			<0.001
No	7875(38.2)	9587(38.5)		1973(32.6)	15470(39.2)	
Yes	12741(61.8)	15314(61.5)		4080(67.4)	23995(60.8)	
Single child, n (%)			0.490			<0.001
No	9360(45.4)	11231(45.1)		2415(39.9)	18193(46.1)	
Yes	11256(54.6)	13671(54.9)		3638(60.1)	21272(53.9)	
Prematurity, n (%)			0.001			0.016
No	19565(94.9)	23781(95.5)		5726(94.6)	37610(95.3)	
Yes	1051(5.1)	1121(4.5)		327(5.4)	1855(4.7)	
Delivery mode, n (%)			0.703			<0.001
Eutocia	9050(43.9)	10882(43.7)		2512(41.5)	17404(44.1)	
Caesarean	11566(56.1)	14020(56.3)		3541(58.5)	22061(55.9)	
Feeding pattern, n (%)			0.082			<0.001
Breast feeding	5360(26.0)	6300(25.3)		1525(25.2)	11169(28.3)	
Mixed feeding	13009(63.1)	15962(64.1)		3735(61.7)	27783(70.4)	
Artificial feeding	2247(10.9)	2640(10.6)		793(13.1)	513 (1.3)	
Maternal age at child birth; mean (SD)	27.49(4.01)	27.37(4.08)	0.002	26.53(3.95)	27.57(4.05)	0.011
Paternal age at child birth; mean (SD)	29.85(4.71)	29.71(4.72)	0.001	28.92(4.59)	29.91(4.73)	<0.001

Maternal education, n (%)			0.435			<0.001
Primary or secondary	3587(17.4)	4233(17.0)		1307(21.6)	8801(22.3)	
High school	5752(27.9)	7122(28.6)		1901(31.4)	2644(6.7)	
College	10679(51.8)	12899(51.8)		2845(47.0)	28020(71.0)	
Postgraduate	598(2.9)	648(2.6)				
Family income, RMB/month, n (%)			0.273			<0.001
<5000	2268(11.0)	2640(10.6)		805(13.3)	4104(10.4)	
5000-10000	5092(24.7)	6026(24.2)		1780(29.4)	9353(23.7)	
10000-20000	7257(35.2)	8890(35.7)		2106(34.8)	14050(35.6)	
>20000	5999(29.1)	7246(29.5)		1362(22.5)	11958(30.3)	
Maternal marital status, n (%)			0.581			<0.001
Married	19915(96.6)	24030 (96.5)		5793(95.7)	38163(96.7)	
Unmarried/Divorced/Windowed	701(3.4)	872(3.5)		260(4.3)	1302(3.3)	
Gestation smoking, n (%)			0.147			0.007
No	20224(98.1)	24379(97.9)		5896(97.4)	38676(98.0)	
Yes	392(1.9)	523(2.1)		157(2.6)	789(2.0)	
Gestation passive smoking, n (%)			<0.001			<0.001
No	15586(75.6)	17207(69.1)		3759(62.1)	29046(73.6)	
Yes	5030(24.4)	7695(30.9)		2294(37.9)	10419(26.4)	
Gestation drinking, n (%)			0.920			0.148
No	20307(98.5)	24528(98.5)		5980(98.8)	38873(98.5)	
Yes	309(1.5)	374(1.5)		73(1.2)	592(1.5)	
Taken folic acid during pregnancy, n (%)			0.238			0.002
No	1979(9.6)	2465(9.9)		660(10.9)	5052(12.8)	
Yes	18637(90.4)	22437(90.1)		5393(89.1)	34413(87.2)	
Taken vitamins during pregnancy, n (%)			0.019			0.288
No	12803(62.1)	15215(61.1)		3765(62.2)	24271(61.5)	

Yes	7813(37.9)	9687(38.9)		2288(37.8)	15194(38.5)	
Taken calcium during pregnancy, n (%)			0.489			0.012
No	3113(15.1)	3685(14.8)		968(16.0)	5841(14.8)	
Yes	17503(84.9)	21217(85.2)		5085(84.0)	33624(85.2)	
Number of person residence, n (%)			<0.001			0.029
≤4	14596(70.8)	17182(69.0)		4298(71.0)	27468(69.6)	
>4	6020(29.2)	7720(31.0)		1755(29.0)	11997(30.4)	
Average daily sleep duration / h (0-1 years old)	16.38(3.24)	16.43(3.25)	0.166	16.09(3.28)	16.41(3.24)	<0.001
Average daily sleep duration / h (1-3 years old)	11.75(1.86)	11.81(1.91)	0.003	11.63(1.82)	11.81(1.89)	<0.001

Table 2. Association of exposure to cooking during gestation with child hyperactive behaviors

Independent variables	N	Hyperactive behaviors: dichotomous measure (OR, 95% CI)		continuous measure (β, 95% CI)	
		Model 1	Model 2	Model 1	Model 2
Cooking					
No	24902	Ref	Ref	-	-
Yes	20616	1.15(1.09-1.21) ***	1.17(1.10-1.24) ***	0.015(0.011-0.020) ***	0.019(0.015-0.024) ***
Cooking fumes					
Little	20325	Ref	Ref	-	-
A lot of	291	2.63(2.04-3.40) ***	1.83(1.38-2.44) ***	0.130(0.100-0.159) ***	0.072(0.041-0.102) ***
Frequency of cooking					
Never	24902	Ref	Ref	-	-
Occasionally	14294	0.99(0.93-1.06)	1.04(0.98-1.12)	0.001(-0.004-0.006)	0.009(0.004-0.015) ***
Sometimes	5361	1.34(1.24-1.46) ***	1.32(1.21-1.44) ***	0.032(0.025-0.040) ***	0.030(0.023-0.038) ***
Often	578	2.18(1.79-2.65) ***	1.92(1.55-2.38) ***	0.044(0.023-0.065) ***	0.042(0.033-0.045) *
Always	383	3.33(2.68-4.13) ***	2.40(1.88-3.05) ***	0.178(0.153-0.203) ***	0.131(0.105-0.157) ***
Type fuels of cooker used					
Electricity	14212	Ref	Ref	-	-
Nature gas	5154	2.20(2.02-2.40) ***	1.69(1.51-1.90)***	0.116(0.108-0.124) ***	0.075(0.065-0.085) ***
Liquefied petroleum gas	1016	2.29(1.96-2.69) ***	1.75(1.46-2.10) ***	0.118(0.102-0.134) ***	0.075(0.058-0.092) ***
Coal and others	234	3.02(2.25-4.05) ***	2.16(1.56-2.99)***	0.159(0.127-0.191) ***	0.104(0.071-0.138) ***
Ventilation condition					
Good	10149	Ref	Ref	-	-
Fairy good	8579	1.13(1.04-1.23)**	1.03(0.94-1.13)	0.024(0.018-0.032) ***	0.010(0.003-0.018) **
Poor	1888	2.61(2.32-2.94)***	1.68(1.46-1.94) ***	0.148(0.135-0.160) ***	0.077(0.063-0.091) ***

†Model 1 was adjusted for none confounding variables; Model 2 was adjusted for child sex and age, migrant or not, maternal and paternal age at birth, maternal and paternal education, family income, marital status, parity, multivitamins supplementation during pregnancy, passive smoking during pregnancy, feeding pattern, premature birth, average daily sleep duration (0-1 and 1-3 years old), and frequency of parent-child interaction(0-1 and 1-3 years old). * P<0.05, ** P<0.01, *** P<0.001

Table 3. Association of cooking fumes and ventilation condition with child hyperactive behaviors at around 3 years old.

Cooking fumes	Ventilation condition	n	Crude OR (95%CI)	Adjusted †OR (95%CI)
Little	Good/ Fairy good	18530	Ref	Ref
Little	Poor	1795	2.39(2.14-2.68) ***	1.63(1.43-1.87) ***
A lot of	Good/ Fairy good	198	2.19(1.57-3.03) ***	1.71(1.20-2.45) **
A lot of	Poor	93	4.93(3.26-7.46) ***	3.07(1.93-4.87) ***

†- adjusted for child sex and age, migrant or not, maternal and paternal age at birth, maternal and paternal education, family income, marital status, parity, multivitamins supplementation during pregnancy, passive smoking during pregnancy, feeding pattern, premature birth, average daily sleep duration (0-1 and 1-3 years old), and frequency of parent-child interaction(0-1 and 1-3 years old). * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Table 4. Association of exposure to cooking during gestation with child hyperactive behaviors, stratified by covariates

	n	†OR (95%CI)	†β(95%CI)
Overall	45518	1.16(1.10-1.22)	0.016(0.012-0.021)
Migrant or not			
No	17462	1.12(1.01-1.23)	0.009(0.002-0.016)
Yes	28055	1.18(1.10-1.26)	0.020(0.015-0.026)
Maternal education			
Primary or secondary	7820	1.31 (1.16-1.48)	0.033(0.022-0.045)
High school	12874	1.19(1.08-1.31)	0.021(0.012-0.029)
College	23578	1.08(1.00-1.17)	0.009(0.003-0.015)
Postgraduate	1246	1.00(0.67-1.49)	-0.005(-0.032-0.023)
Family income, RMB/month			
<5000	4908	1.31(1.12-1.53)	0.028(0.014-0.043)
5000-10000	11118	1.18(1.06-1.31)	0.025(0.016-0.034)
10000-20000	16147	1.14 (1.04-1.25)	0.012(0.005-0.020)
>20000	13245	1.09(0.98-1.23)	0.009(0.0007-0.017)
Gestation smoking			
No	44603	1.16(1.10-1.23)	0.016(0.011-0.02)
Yes	915	1.11(0.77-1.61)	0.038(0.002-0.076)
Gestation passive smoking			
No	32793	1.12(1.04-1.20)	0.008(0.003-0.013)
Yes	12725	1.36(1.24-1.49)	0.053(0.044-0.062)
Number of person residence			
≤4	31778	1.14(1.07-1.22)	0.021(-0.064-0.107)
>4	13740	1.20(1.09-1.33)	0.015(0.001-0.029)
Feeding pattern			
Breastfeeding	11660	1.19(1.07-1.33)	0.012(0.003-0.021)
Mixed feeding	28971	1.16(1.09-1.25)	0.020(0.014-0.025)
Artificial feeding	4887	1.06(0.91-1.24)	-0.005(-0.009-0.019)
Gestation folic acid supplementation			
No	4444	1.25(1.06-1.48)	0.021(0.009-0.033)
Yes	41074	1.15(1.08-1.22)	0.015(0.010-0.020)
Gestation multi-vitamin supplementation			
No	28018	1.15(1.08-1.24)	0.016(0.011-0.066)
Yes	17500	1.16(1.06-1.27)	0.015(0.008-0.023)
Gestation calcium supplementation			
No	6798	1.21(1.05-1.39)	0.021(0.009-0.033)
Yes	38720	1.15(1.08-1.22)	0.015(0.010-0.020)

†-adjusted for child age, child sex, maternal and paternal age at birth.

Table 5. Fully-adjusted combined associations between prenatal cooking exposure and child hyperactive behaviors among participants with prenatal outdoor air pollution exposure available
(n=28712)

Independent variables	N	Hyperactive behaviors: dichotomous measure (OR, 95% CI)		Hyperactive behaviors: continuous measure (β, 95% CI)	
		Model 1	Model 2	Model 1	Model 2
Cooking					
No	15848	Ref	Ref	-	-
Yes	12864	1.20(1.11-1.30) ***	1.18(1.10-1.28) ***	0.018(0.012-0.024) ***	0.017(0.011-0.023) ***
Cooking fumes					
Little	12686	Ref	Ref	-	-
A lot of	178	2.30(1.61-3.30)	2.29(1.59-3.30)	0.091(0.052-0.130) ***	0.086(0.045-0.124) ***
Frequency of cooking					
Never	15848	Ref	Ref	-	-
Occasionally	8941	1.07(0.98-1.17)	1.07(0.98-1.17)	0.009(0.003-0.016) **	0.010(0.003-0.016) **
Sometimes	3305	1.35(1.20-1.52) ***	1.33(1.18-1.50) ***	0.025(0.015-0.034) ***	0.023(0.014-0.032) ***
Often	374	2.09(1.58-2.75) ***	1.71(1.29-2.26) ***	0.042(0.014-0.058) ***	0.039(0.012-0.047) ***
Always	244	2.48(1.82-3.39) ***	2.09(1.53-2.86) ***	0.139(0.108-0.171) ***	0.100(0.069-0.131) ***
Type fuels of cooker used					
Electricity	9318	Ref	Ref	-	-
Nature gas	3004	1.59(1.21-2.08) ***	1.21(1.12-1.52) ***	0.054(0.030-0.078) **	0.027(0.004-0.051) *
Liquefied petroleum gas	482	1.68(1.44-1.95) ***	1.31(0.92-1.59)	0.073(0.060-0.086) ***	0.046(0.033-0.059) ***
Coal and others	60	1.97(1.02-3.81) *	1.63(0.84-3.18)	0.107(0.042-0.172) ***	0.088(0.024-0.151) **
Ventilation condition					
Good	6387	Ref	Ref	-	-
Fairy good	5646	1.07(0.95-1.22)	0.96(0.84-1.09)	0.019(0.009-0.028) ***	0.010(0.001-0.019) *
Poor	831	1.97(1.61-2.43) ***	1.65(1.34-2.03) ***	0.085(0.065-0.104) ***	0.070(0.051-0.090) ***

†- Model 1 adjusted for child sex and age, migrant or not, maternal and paternal age at birth, maternal and paternal education, family income, marital status, parity, multivitamins supplementation during pregnancy, passive smoking during pregnancy, feeding pattern, premature birth, average daily sleep duration (0-1 and 1-3 years old), and frequency of parent-child interaction(0-1 and 1-3 years old); Model 2 adjusted all variables in Model 1 and prenatal outdoor air pollution exposure($PM_{2.5}$ and NO_2). * P<0.05, ** P<0.01, *** P<0.001