

Original Article



Cooking-Related Solid Fuel Combustion and Memory-Related Cognitive Disorders: Evidence from the CHARLS Cohort

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Abstract:

Introduction: Memory-Related Cognitive Disorders keeps growing alongside global population ageing. Air pollution is harmful to health, yet evidence linking household solid fuel cooking to amnesic disorders remains insufficient. Our purpose is to study the impact of solid fuel consumption for cooking on amnesic disorders.

Methods: Data were obtained from the 2015–2018 China Health and Retirement Longitudinal Study (CHARLS), including 6141 initially amnesic disorder-free participants aged ≥ 45 years. We employed propensity score matching (PSM) to balance sociodemographic characteristics, lifestyle, health status, and other covariates. Logistic regression was applied to the matched data to examine the association between solid fuel consumption and amnesic disorders, with subgroup analyses conducted to assess heterogeneity.

Results: The results showed that among 6141 participants, 119 developed incident amnesic disorders. The population was significantly higher in the solid fuel group than in the clean fuel group (2.64% vs. 1.40%, $P < 0.001$). After PSM adjustment for confounders, solid fuel use for cooking was associated with a higher risk of amnesic disorders (OR = 2.125, 95% CI: 1.308, 3.453). Similar associations were observed in subgroups aged ≥ 60 years, males, rural residents, and individuals with depression.

Conclusion: In conclusion, solid fuel consumption is associated with an increased risk of incident amnesic disorders among Chinese adults aged 45 years and older. It is vital to raise public health awareness, implement intervention measures, minimize the use of solid fuels, and encourage the use of clean fuels, all of which will reduce the occurrence of air pollution-related diseases.

Key words: Solid fuels; Memory-Related Cognitive Disorders; Household air pollution; CHARLS

Introduction

As the world's population ages, the number of dementia cases increases¹. According to the World Alzheimer Report 2022, around 55 million people worldwide had dementia in 2019, with a projected 139 million by 2050². China's annual cost of treating dementia is predicted to exceed \$1.8 trillion by 2050³. Brain atrophy is a amnesic disorders that is a warning indication of dementia⁴. Aside from dementia, the prevalence

of Parkinson's disease⁵ and other amnesic disorders has increased. Parkinson's disease affected 6.1 million people globally in 2016, and conservative predictions predict that this figure will double by 2050⁶.

Air pollution is the primary environmental killer and the fifth leading cause of mortality worldwide⁷. In addition to data tying air pollution

to respiratory disease, stroke, heart disease, and other illnesses, new epidemiological studies have connected air pollution to an increased risk of dementia, Alzheimer's disease, and Parkinson's disease^{8,9}. Air pollution encompasses both home air pollution (HAP) and ambient air pollution (AAP)¹⁰. Home environments affect human health more than outdoor environments¹¹. As a result, using biomass or coal to meet domestic energy demands has raised significant concerns about household air pollution¹². An estimated 3.8 million people die annually from household air pollution¹³.

Household air pollution from solid fuels, such as wood, coal, kerosene, agricultural leftovers, or animal dung, leads to exposure to particulate matter (PM) with an aerodynamic diameter smaller than 2.5 μm (PM_{2.5})¹⁴. Approximately 700 million Chinese people rely on solid fuel as their primary source of domestic energy, producing many dangerous air pollutants such as carbon monoxide, organic air pollutants, and high levels of interior household air pollution¹⁵. According to studies, using polluting fuels at home considerably elevated the risk of various cardiometabolic illnesses¹². In epidemiological studies, solid fuel usage was associated with an increased risk of respiratory disease¹⁶. However, little research has investigated the relationship between household air pollution induced by solid fuel consumption and the risk of amnestic disorders.

Given the rising prevalence of amnestic disorders, it is critical to discover the factors that can influence the risk of these diseases. This study used CHARLS, a nationally representative database led by the National School of Development of Peking University in China, which aims to study the health, economic, and social conditions of people aged 45 and above in China, to investigate the relationship between the consumption of solid fuels and new-onset amnestic disorders among middle-aged and

elderly people in China. The study's findings will help influence energy and environmental health policies to lower the risk of dementia, Parkinson's disease, and other amnestic disorders.

Methods

Data Source

The data for this cohort analysis were sourced entirely from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey of Chinese middle-aged and elderly persons aged 45 and up. The national baseline survey was conducted in 2011 and is updated every two to three years¹⁷. The surveys were conducted in 150 counties and 450 villages throughout 28 provinces (autonomous areas and municipalities). When the national follow-up was completed in 2018, there were 19000 interviewees from 12400 households. All methods are carried out in conformity with the relevant guidelines and regulations listed on the CHARLS official website¹⁷.

Our sample consisted of respondents who participated in two surveys in 2015 and 2018, with the 2015 data as the baseline. As illustrated in Figure 1, we excluded individuals under 45 and those with amnestic disorders (such as Alzheimer's disease, cerebral atrophy, and Parkinson's disease) from the 2015 survey data. We also removed individuals who cooked using unidentified fuels. Samples with missing primary results and outliers and those with a history of amnestic disorders at the 2018 follow-up were excluded. Finally, 6141 eligible patients were selected for the subsequent analysis.

New-onset Amnestic Disorders

The outcome variable in this study was the presence or absence of amnestic disorders. The participants were asked, "Has a doctor ever told you that you were diagnosed with one of the memory-related diseases, such as Alzheimer's disease, brain atrophy, or Parkinson's disease?" Participants who replied "yes" during the 2018 follow-up were classified as having newly

diagnosed amnestic disorders.

Solid Fuel Consumption

According to the 2015 questionnaire, "What are the main fuels used for cooking?" Fuels for cooking are classified as solid and clean fuels. Solid fuels consist of coal, briquettes, straw, and firewood. Clean fuels include natural gas, biogas, liquefied petroleum gas (LPG), and electricity. If participants utilize solid fuels to cook, "1" denotes "yes," and "0" represents "no."

Covariates

Prior research and reports in the literature informed the selection of covariates¹⁸⁻²⁰. Covariates included sociodemographic variables like age, gender, marital status, education, and place of residence; lifestyle features like smoking, drinking, sleeping, and socializing; and health statuses like BMI, hypertension, dyslipidemia, and disability.

The interviewees' education level was determined in this study by asking, 'What is the highest degree of education you have achieved now?' Those who did not get an education, graduated from a private school, and did not complete elementary school were classed as illiterate or without formal education. In contrast, those who graduated with six years or more of education were classified as primary school or above. Marital status was categorized as married, living with their spouse, or in other situations (separated, widowed, divorced, etc.). The area of residence was divided into rural and urban zones. The question "How long have you normally taken naps in the past month?" was used to calculate naps. Naps were classified into two categories: ≤ 1 hour and nap length > 1 hour. The question "Have you done any of these activities in the last month?" determines one's social status. Participation in one or more activities is noted as "yes," whereas participation in none of the following activities is marked as "no." BMI is calculated by dividing one's weight by one's height squared and is divided into < 24 and ≥ 24 . The conditions of hypertension and dyslipidemia were graded using the relevant questions from the questionnaire's health status section, with "1" indicating related diseases and "0" indicating none. The CHARLS study used the CES-D-10 (Center for Epidemiological Studies Depression Scale-10) questionnaire to estimate

the likelihood of respondents experiencing depressed symptoms within the previous week. Previous research on the CES-D-10 scale found that the crucial number for detecting depression symptoms in the elderly is 10. To discriminate between participants with and without depressive symptoms, the critical score was established at 10; ≥ 10 is denoted as 1, and < 10 is denoted as 0²¹.

Statistical Analysis

The Shapiro-Wilk normality test was performed to determine the normality of the data in this study. In this investigation, the continuous variables showed a non-normal distribution. The data were represented by the median [M] and interquartile range [Q1, Q3], with categorical variables represented by numbers and percentages. The Pearson chi-square test was used to compare categorical variables, while the Kruskal-Wallis test was employed to compare data from continuous variables with non-normal distributions.

To provide a more accurate comparison between the treatment and control groups, this study employed propensity score matching (PSM) to mitigate the impact of data bias and confounding variables in the study. In PSM, we used the kernel matching approach to match the data and then estimated the propensity score by fitting the logit regression model. The quality of matching was assessed by comparing the treatment and control groups' common range of values. The matched data was then tested for covariate balance. If the *p*-value of the chi-square test after matching was greater than 0.05, as well as the *p*-values of the variables in the treatment and control groups before and after matching, it showed a good matching effect. To investigate the effect of cooking fuels on amnestic disorders, we developed a weighted logistic regression model. Based on official data, we used the INDV_weight_ad2 from the 2018 wave as the sample weight and added the sampling unit (communityID) and stratification information (province) in the model to generate an unbiased estimate of the total population. We explained the association between solid fuels and amnestic disorders using odds ratios (OR) and 95% confidence intervals (CI), and we incorporated several factors to build adjusted models 1–3 to

test the robustness of this relationship. Subsequently, we used weighted regression to analyze subgroups and discover interactions. We studied the risk of amnestic disorders associated with the use of solid fuels in a variety of subgroups, including age, gender, location of residence, marital status, BMI, nap duration, and depressive status. Finally, we investigated the interaction of the subgroup analysis variables and cooking.

All statistical analyses were performed using STATA version MP17.0 software. P -values < 0.05 were considered statistically significant.

Results

The study comprised 6141 people, as shown in Figure 1. Table 1 shows specific characteristics of the population's use of various fuels for cooking. Females comprised 48.79% of the population.

Rural residents used more solid fuels than urban residents ($P < 0.001$). Smokers utilize solid fuels more (50.04%) than cleaner fuels. Individuals with primary and higher education were less likely to use solid fuels than those without formal education ($P < 0.001$).

In our study, 119 participants developed new-onset amnestic disorders. In the baseline data, without considering any other variables, the proportion of the population with new-onset amnestic disorders was higher in the solid fuel group than in the clean fuel group (2.64% vs 1.40%, $P < 0.001$, Table 1). Except for gender, marital status, alcohol use, nap time, hypertension, and depression, most characteristics show statistical variations between people who utilize different types of fuels.

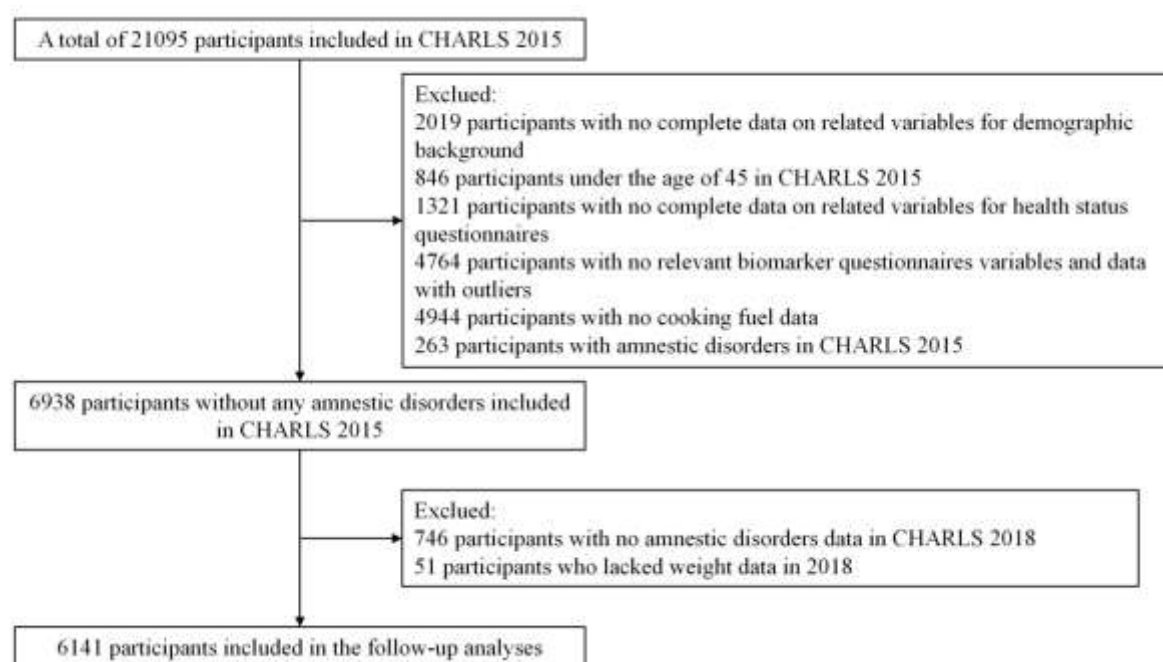


Figure 1. Flow chart of the selection process of participants.

Table 1. Basic characteristics of people using clean fuels and solid fuels

	Clean fuel users (N=3493)		Solid fuel users (N=2648)		
Variable	N(M)	N%(Q1,Q3)	N(M)	N%(Q1,Q3)	p-value
Age	60	(52,66)	62	(55,68)	<0.001
Gender					
Male	1755	50.24	1390	52.49	0.081
Female	1738	49.76	1258	47.51	
Residence					

City or town	1250	35.79	227	8.57	<0.001
Village	2243	64.21	2421	91.43	
Education					
Illiterate or no formal education	1157	33.12	1353	51.10	<0.001
Elementary school or above	2336	66.88	1295	48.90	
Marital status					
Married and living with spouse	2621	75.04	1986	75.00	0.974
Others	872	24.96	662	25.00	
Smokers	1557	44.57	1325	50.04	<0.001
Drinkers	1315	37.65	940	35.50	0.084
Nap time					
<=1h	2814	80.56	2150	81.19	0.533
>1h	679	19.44	498	18.81	
Social					
Yes	2201	63.01	1316	49.70	<0.001
No	1292	36.99	1332	50.30	
Bmi(kg/m ²)	24.22	(21.62,26.53)	23.57	(20.88,25.89)	<0.001
Hypertension	1126	32.24	837	31.61	0.602
Dyslipidemia	579	16.58	347	13.10	<0.001
Disability	978	28.00	1027	38.78	<0.001
Depression	3271	93.64	2490	94.03	0.531
Amnestic disorders_new	49	1.40	70	2.64	<0.001

As indicated in Supplementary Table 1, in the unadjusted model, cooking with solid fuel was associated with an increased risk of neurological diseases (OR = 1.88, 95%CI: 1.21,2.92). Meanwhile, when different covariates were added to form new models, the consumption of solid

fuel for cooking still increased the risk of amnestic disorders (adjusted model 1 OR = 2.24, 95%CI: 1.39,3.60; adjusted model 2 OR = 2.23, 95%CI: 1.37,3.62; adjusted model 3 OR = 2.12, 95%CI: 1.31,3.45).

Supplementary Table 1. The risk of New-onset amnestic disorders from cooking with solid fuels

	Sensitivity analysis							
	Unadjusted model		Adjusted model 1		Adjusted model 2		Adjusted model 3	
Outcomes	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Clean fuels	1(ref)		1(ref)		1(ref)		1(ref)	
Solid fuels	1.88 (1.21,2.92)	0.005	2.24 (1.39,3.60)	0.001	2.23 (1.37,3.62)	0.001	2.12 (1.31,3.45)	0.002

Model 1: with adjustment for age,gender,residence,education,marital status

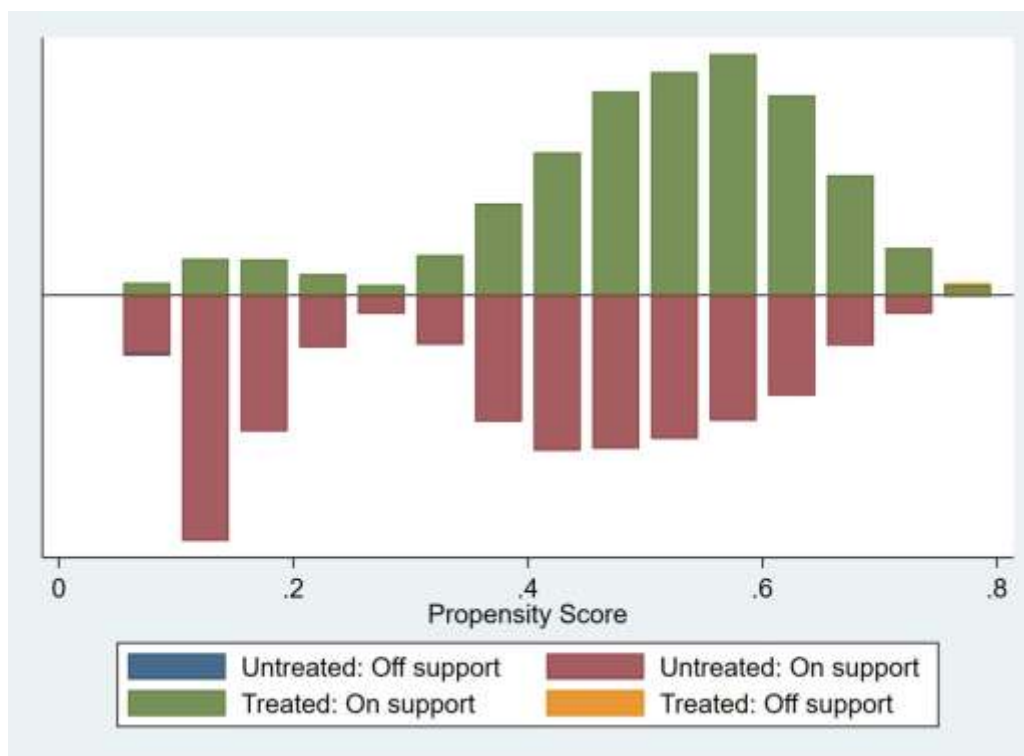
Model 2: Add smoking, drinking, nap time and social in Model 1

Model 3: Add BMI, hypertension, dyslipidemia, disability and depression in Model 2

Ref: reference category for calculating odds ratios of solid fuels

To assess the matching efficiency, we conducted various tests to verify the stability of PSM. Supplementary Figure 1 depicts the standard range of propensity ratings for matching data. Most of the observed values are within a common

range, with only a few samples deviating from support after matching. Supplementary Figures 2 and 3 depict the density functions of propensity scores before and after matching. Following matching, the distribution of the treatment and control groups became more comparable.



Supplementary Figure 1. The common range of propensity scores



Supplementary Figure 2. The density functions of propensity scores before matching



Supplementary Figure 3. The density functions of propensity scores after matching

Supplementary Table 2 and Figure 2 show the results of the covariate balancing test. The covariate standard deviations were dramatically reduced after matching, with the absolute standard deviation (ASB) all falling below 5%. The balance test had a pseudo-R² of less than 0.01, and the likelihood ratio test for combined

significance after pairing was insignificant ($P = 0.998$). A series of results showed that after matching, there was no systematic difference between the treatment and control groups, and the data matching quality was acceptable. The matched data were used in the following heterogeneity analysis.

Supplementary Table 2. Covariate balancing test

Variable	Mean		Bias (%)	Bias reduction (%)	t	p-value
	Treated	Control				
Age	61.922	61.681	2.6	86.5	0.95	0.342
Gender	0.475	0.475	0.1	98.7	0.02	0.984
Residence	0.914	0.917	-0.8	98.8	-0.42	0.673
Education	0.490	0.500	-2.1	94.3	-0.75	0.455
Marital status	0.250	0.251	-0.3	-234.9	-0.10	0.920
Smokers	0.500	0.495	0.9	92.1	0.31	0.754
Drinkers	0.355	0.355	0.1	98.6	0.02	0.982
Nap time	0.188	0.193	-1.3	19.6	-0.47	0.638
BMI	23.574	23.660	-2.3	86.8	-0.85	0.396
Hypertension	0.316	0.319	-0.6	54.4	-0.22	0.823
Dyslipidemia	0.131	0.130	0.4	96.0	0.15	0.882
Disability	0.387	0.376	2.4	89.7	0.83	0.408
Social	0.498	0.507	-1.8	93.3	-0.64	0.519
Depression	0.940	0.939	0.6	63.3	0.22	0.828

Sample	Pseudo R2	LR chi2	$p > \chi^2$	Mean Bias	R	Var (%)
Unmatched	0.107	894.44	0.000	16.3	0.47*	0
Matched	0.000	3.45	0.998	1.2	1.08	0

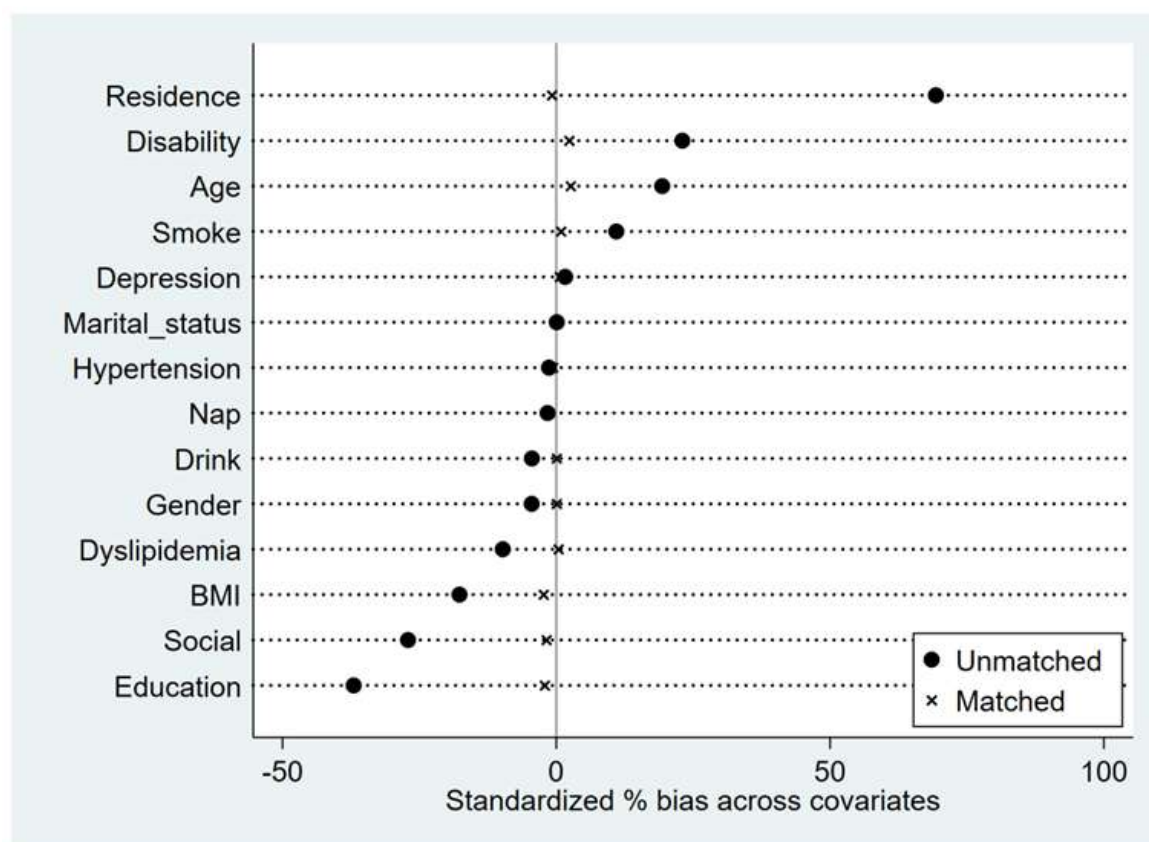


Figure 2. The covariate balancing test

Table 2 shows the effects of using solid fuels on amnestic disorders before and after PSM. The OR values were significantly different before and after PSM. For the matched model, after controlling for potential confounding factors,

respondents who used solid fuel during cooking had a higher risk of amnestic disorders compared to those who used clean fuel, with an OR value of 2.125 (Table 2, 95% CI: 1.308, 3.453).

Table 2. The effects of using solid fuels on amnestic disorders before and after PSM

Outcomes	Unmatched model		Matched model	
	OR (95% CI)	<i>P</i>	OR (95% CI)	<i>P</i>
Clean fuels	1(ref)		1(ref)	
Solid fuels	2.123(1.306,3.452)	0.002	2.125(1.308,3.453)	0.002

We then evaluated the diverse impacts of age, gender, place of residence, marital status, BMI level, nap time, and depression on the risk of amnestic disorders caused by solid fuel usage. As shown in Figure 3, there was a positive correlation between solid fuel use and amnestic

disorders in the group older than 60 years (≥ 60 OR = 2.00, 95% CI: 1.21, 3.32). There was a correlation between solid fuels and amnestic disorders in the male groups (male OR = 1.99, 95% CI: 1.44, 4.94). Based on their residence, the village group discovered a link between solid

fuels and amnestic disorders (OR = 2.44, 95% CI: 1.48, 4.03, Figure 3). There was a significant association between solid fuel use and the incidence rate of amnestic disorders in the depression population (OR = 2.12, 95% CI: 1.36, 3.32, Figure 3).

Furthermore, in each subgroup, the use of solid fuel for cooking was positively correlated with the occurrence of amnestic disorders, regardless of their marital status [(cohabitated OR = 2.23, 95% CI: 1.21, 4.11), (others OR = 1.88, 95% CI: 1.01, 3.50)], napping habits [≤ 1 h OR = 1.79, 95% CI: 1.10, 2.91), (>1 h OR = 3.84, 95% CI: 1.58, 9.34)], or BMI categorization [<24 OR = 2.34, 95% CI: 1.29, 4.22), (≥ 24 OR = 1.89, 95%

CI: 1.03, 3.48)] (Figure 3). Overall, we discovered no differences in the impact of solid fuels for cooking on amnestic disorders between the subgroups described above (subgroups $p = 0.885$, $p = 0.389$, $p = 0.360$, $p = 0.720$, $p = 0.313$, $p = 0.644$, $p = 0.752$, Figure 3). The subgroup distribution of 119 individuals diagnosed with new-onset amnestic disorders is provided in Supplementary Table 3. Subsequently, we investigated the interaction of subgroup analysis variables with cooking. The findings are provided in Supplementary Figure 4. However, according to the research findings, no interaction between these variables and cooking has been discovered thus far

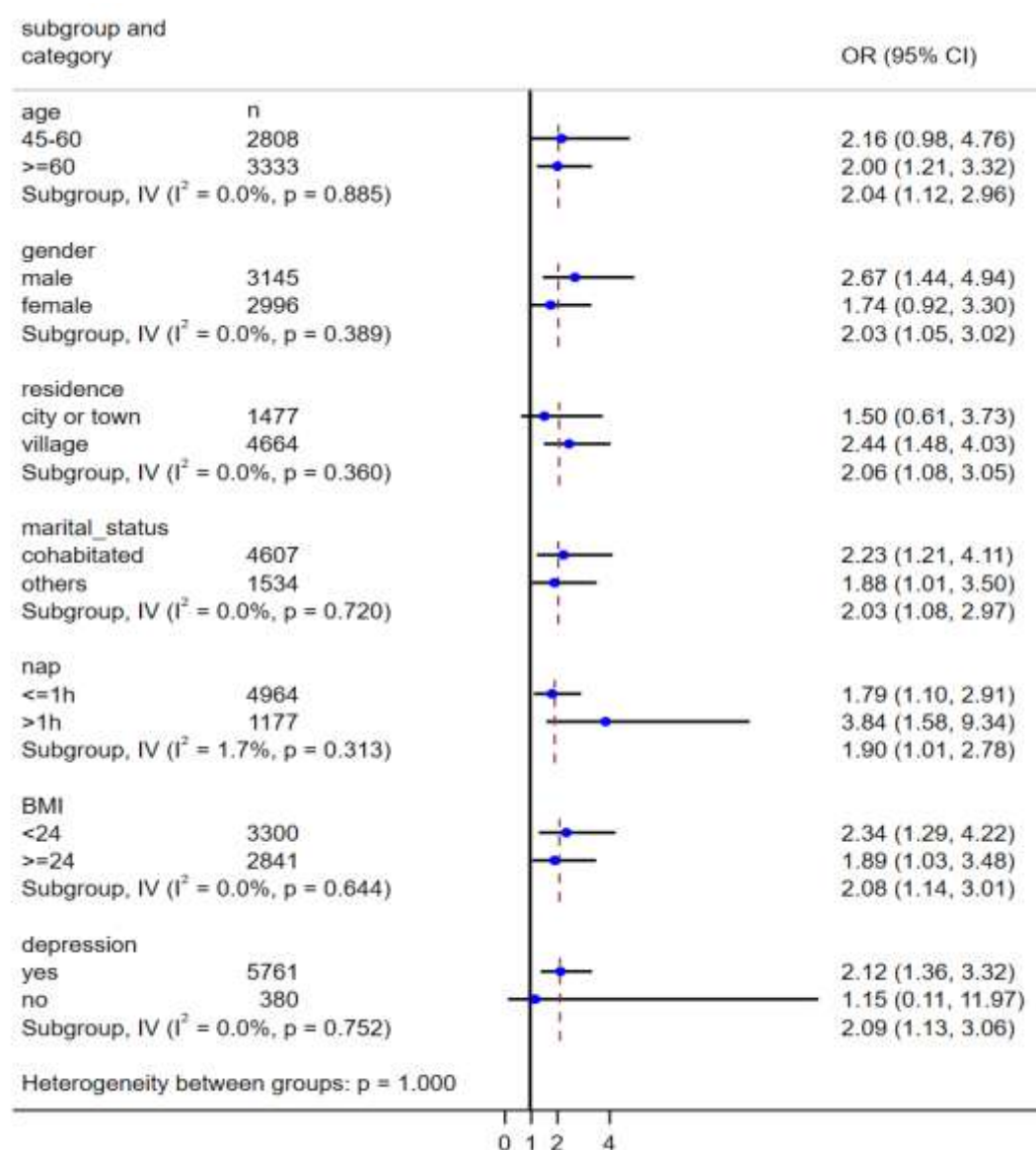
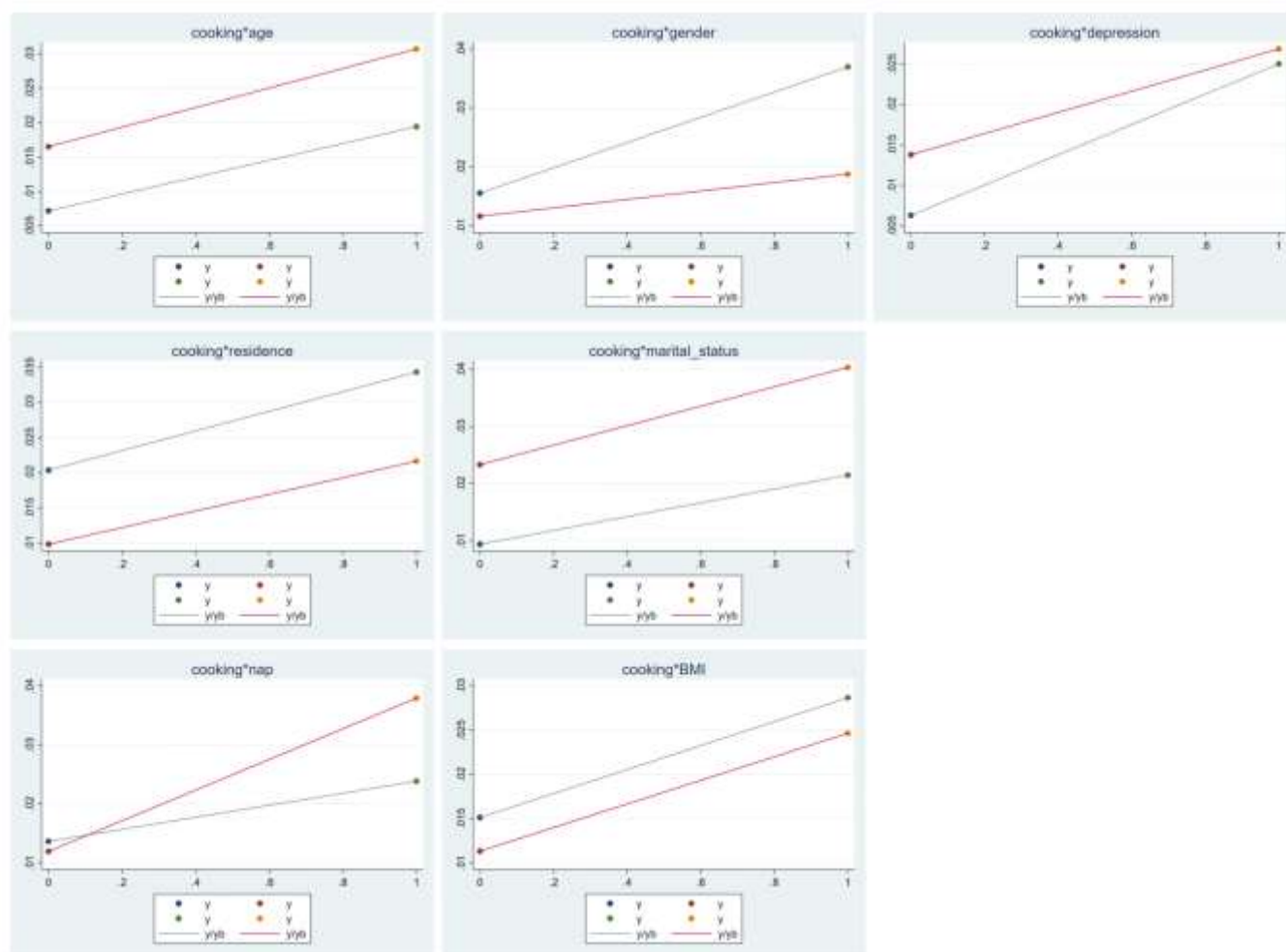


Figure 3. Subgroup analysis of forest plot



Supplementary Figure 4. Multiplicative and marginal interaction effects

The interaction effects between each subgroup and cooking were not significant.

Discussion

Currently, almost 2.4 billion people worldwide cook with solid fuels. For over 290 million individuals in China, solid fuels represent their primary energy source for cooking²². Previous studies have shown that consuming solid fuels can harm one's health. An increased risk of arteriosclerotic cardiovascular disease has been associated with the usage of solid fuel²³. Furthermore, it has been shown that using solid fuel for cooking and heating raises the risk of arthritis²⁴. Prolonged exposure to solid fuels used in cooking has been associated with an increased risk of major depressive episodes²⁵. According to the studies above, using solid fuels and air

pollution in homes hurts people's physical and emotional well-being.

In this nationally representative study, we found that household solid fuel use for cooking had a significant impact on the risk of amnestic disorders in the middle-aged and elderly Chinese population (Table 2, OR = 2.125, $P = 0.002$) after controlling for relevant covariates such as demography, lifestyle, and health status by propensity score matching (PSM). This is in line with the previous observations that the long-term usage of solid fuels raises the risk of developing disorders like diabetes and stroke^{26,27}.

Solid fuels were positively correlated with the occurrence of amnestic disorders in the over-60 age group (OR = 2.00, 95% CI: 1.21, 3.32, Figure 3). Previous research has found that as people age, the negative effects of air pollution on

cognition become more pronounced²⁸. This also emphasizes that people of all ages should avoid utilizing solid fuels for safety reasons. The association between solid fuels and amnestic disorders has also been demonstrated in the male groups (OR = 2.67, 95% CI: 1.44,4.94, Figure 3). According to studies, males lose more life years due to solid fuel consumption than females, and the negative consequences of environmental air pollution are likewise more substantial in males^{22,29,30}. This could be attributed to females having a smaller airway width and lung volume, resulting in a lower peak expiratory flow and lung capacity, lowering their intake of air pollutants³¹.

A significant association between solid fuel use and amnestic disorders incidence was observed in the village group (OR = 2.44, 95% CI: 1.48,4.03, Figure 3). According to studies, solid fuel emissions in rural areas contribute more to PM_{2.5}, rural residents are more likely to die as a result of air pollution than urban residents³², and they are also more likely to develop chronic diseases (such as cardiovascular disease)³³, which is consistent with our findings. Research has indicated that the use of solid fuel raises the prevalence of depression³⁴, and depression is associated with the development of disorders connected to memory³⁵. The aforementioned data may support our findings, which revealed that the usage of solid fuels among depressed people is positively connected with amnestic disorders (OR = 2.12, 95% CI: 1.36,3.32, Figure 3).

Although there was no significant difference between subgroups, our findings revealed substantial associations between solid fuels and amnestic disorders in rural and city populations (Figure 3). According to studies, married/cohabiting people, whether male or female, all spend more time cooking daily^{36,37}. Some studies have also discovered that the longer the cooking time, the higher the concentration of PM₁₀ in the cooking area, particularly in poorly ventilated areas³⁸.

Therefore, we included the marital status in the subgroup analysis. Research has suggested a bidirectional association between napping and dementia. Napping for more than an hour dramatically raised the risk of dementia³⁹. Excessive daytime napping might affect or reflect abnormalities in brain circadian rhythm control, which is also a precursor symptom of Alzheimer's disease⁴⁰. Previous research found that obesity was linked to cardiovascular metabolic disorders induced by air pollution¹⁴. Air pollution was thought to cause oxidative stress and systemic inflammation, whereas obesity was regarded as a chronic oxidative stress and inflammatory state⁴¹. As a result, we added the napping duration and BMI index to the subgroup analysis. Different subgroups of these two categories demonstrated a link between solid fuel and amnestic disorders. However, no significant differences in disease incidence were observed between subgroups (Figure 3). Other factors, such as socioeconomic position, may impact neurodegenerative illnesses beyond those mentioned in this article. Lower socioeconomic position increases the incidence of anemia in rural China due to the usage of cooking fuels⁴². However, no studies have been conducted to investigate the relationship between the usage of solid fuels and neurodegenerative illnesses in people from various socioeconomic backgrounds. We speculate that since people from different socioeconomic backgrounds have different tendencies towards using fuel for cooking, this might affect the risk of developing amnestic disorders. Further data gathering and verification are required for the speculation mentioned above.

Potential Mechanisms

The exact mechanism by which solid fuel use raises the risk of amnestic disorders is unknown. When utilizing solid fuel for cooking and heating furnaces, it is difficult to thoroughly burn and generate complete combustion products such as carbon dioxide, instead releasing incomplete combustion products such as CO, NO₂, PM, and

some volatile organic compounds⁴³. These PM and gas pollutants can cause oxidative stress in the respiratory epithelium, producing reactive oxygen species (ROS) and gene activation⁴⁴. Some microparticles and soluble components can cross the blood-brain barrier and enter the central nervous system. These particles cause harm to brain tissue by inducing inflammation and cell death^{45,46}.

Strengths and Limitations

For the first time, we discovered that the usage of solid fuels in households is highly related with the development of amnestic disorders such as dementia and Parkinson's disease. Meanwhile, we used propensity score matching to manage variables and selection bias in the study. Furthermore, this study offered new data on the influence of solid fuel use on physical health and gave helpful information for developing public health initiatives.

There are limits to our research as well. First, we added essential factors such as demographics, lifestyle, and health status to control potential confounding effects. However, physical activity, population economy, indoor ventilation, house size, and number of rooms, all of which may be associated with amnestic disorders, were excluded from the study due to a lack of relevant information or a small sample population. Secondly, diagnosing amnestic disorders is self-reported rather than based on medical records, which may lead to misjudgments. Third, it is well-known that solid fuel for heating is prevalent in some areas of China, especially in northern China. We only examined the link between amnestic disorders and solid-fuel cooking; we did not examine the relationship between solid-fuel heating and amnestic disorders because the study only included a small number of individuals who used solid fuel for heating. Fourth, because the exposure dose and duration were not clearly

mentioned in the database, we were unable to further elucidate their impact on this study. However, in future studies, we can refer to and combine other relevant databases to acquire more complete information on the consumption of solid fuel.

Conclusion

Dementia, cerebral atrophy, Parkinson's disease, and other amnestic disorders are growing increasingly prevalent as the world's population ages. Using propensity score matching, this study discovered a strong relationship between solid fuel consumption and amnestic disorders in a representative sample of middle-aged and elderly Chinese persons. After controlling for relevant variables, the study's findings revealed that using solid fuels for cooking was associated with a higher prevalence of amnestic disorders than using clean fuels. Furthermore, among people over 60, male, living in villages, and suffering from depression, the consumption of solid fuels was significantly associated with amnestic disorders. Finally, our findings highlight the importance of multi-pronged approaches to reducing exposure to solid fuel, such as limiting solid fuel use, improving clean fuel supply, improving public health work and intervention measures, and mitigating the impact of diseases caused by air pollution.

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Declaration

The authors declare no conflicts of interest or funding. Generative AI was utilized solely for language editing; the authors assume full responsibility for the scientific content, while AI played no role in data analysis or result generation.

Clinical Trial Number

Not applicable.

Author Contributions (Use CRediT terms)

Conception and design of study: Juan Du, Zhihua Wang; Collating data: Ruonan Sun, Xianling Liang, Man Luo, Zhihua Wang; Analysis and/or interpretation of data: Ruonan Sun, Man Luo, Yueyang Hu, Lei Wu; Drafting the manuscript: Ruonan Sun, Man Luo; Revising the manuscript critically: Juan Du.

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Ethics Declarations: Ethics approval and consent to participate

The original CHARLS was approved by the ethics review committee of Peking University, Ethics approval number: IRB00001052-11-15, and all participants gave written informed consent at the time of participation.

Consent for Publication: Not applicable.

Data Availability statements

The data used in the study are accessible to be downloaded publicly at <https://charls.charlsdata.com/pages/data/111/zh-cn.html>

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