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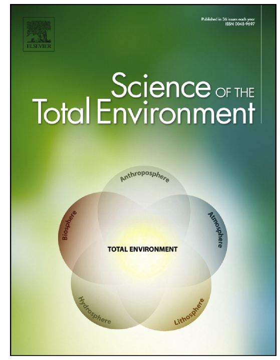

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The effects of indoor air pollution from solid fuel use on cognitive function among middle-aged and older population in China

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The effects of indoor air pollution from solid fuel use on cognitive function among the middle-aged and older population in China

Abstract:

Objectives Growing evidence has linked outdoor air pollution exposure with higher risk of cognitive impairments. However, the role of indoor air pollution in cognitive decline is not well elaborated. By using nationally representative longitudinal data, this study aimed to explore the effects of indoor air pollution from solid fuel use on cognitive function among middle-aged and older individuals in China.

Methods Data were obtained from 2011-2015 waves of CHARLS (China Health and Retirement Longitudinal Study). Scores from the Telephone Interview of Cognitive Status and figure drawing/word recall tests were used to measure cognitive function in 39,482 individuals. Exposure to indoor air pollution was measured as use of solid fuel for cooking. Solid fuel was defined as coal, biomass charcoal, wood, and straw; clean fuel was defined as liquefied gas, natural gas, and electricity. Linear mixed effect models were applied to examine the effect of indoor air pollution from solid fuel use on cognitive function.

Results Participants had an average global cognitive function of 9.67 (SD=4.13). Solid fuel users made up 49.71% of participants, but this proportion was much greater among those living in rural areas (64.22%). Compared with clean fuel users, solid fuel users had worse cognitive function. On average, solid fuel users had a 0.81 (95%CI: -0.89,-0.73) lower global cognition score, 0.63 (95%CI: -0.69,-0.57) lower mental health score, and 0.16 (95%CI: -0.22,-0.14) lower episodic memory score. These effects were stronger among participants who are female, aged 65 years old and above, have education level of primary school and below, or have cardiovascular diseases.

Conclusions These results provide evidence for the role of indoor air pollution in neurobehavioral disorders in China. Promotion of practices like expanded use of clean fuel and improved stoves in households may be crucial to significantly reduce indoor air pollution and protect mental health.

Keywords: Indoor air pollution; solid fuel use; cognitive function

Introduction

Cognitive decline or impairment is considered a preclinical state of Alzheimer's disease and other forms of dementia (1), which reduces quality of life and the abilities of memory, learning, reasoning, attention, and language (2). From 2007-2010, over 15% of middle-aged and older adults in low- and middle-income countries suffered from cognitive impairment (3). With rapid population aging, China continues to experience a rise in the prevalence of cognitive impairment (4). Environmental factors, such as lower socioeconomic status (5), urban environmental exposures (6), and environmental pollution (7), are important triggers of cognitive decline. Of these, increasing evidence suggests that air pollution may negatively affect cognitive functioning among older adults (8-10).

Although previous studies have focused on the role of outdoor air pollution in cognitive decline, only a few studies have examined the association between indoor air pollution and cognition (11, 12). Evidence from South India suggested that the risk of cognitive impairment more than doubled in individuals exposed to indoor air pollution (12). A study on Mexican adults found that exposure to indoor air pollution was associated with poor cognitive performance, such as poor ability of verbal learning, verbal fluency, and attention (11).

Combustion of solid fuels (such as fuelwood, coal, straw, and dung) is a dominant source of indoor air pollution, which significantly contributes to public health burden around the world. Nearly 3 billion people, or 41% of households worldwide, use solid fuels for cooking and heating to meet their basic household energy demands, and this is especially widespread in low- and middle-income countries (13). Of these households, solid fuels are often burned in poorly ventilated cooking spaces with inefficient combustion devices, which generate numerous air pollutants such as carbon monoxide, nitrogen dioxide, organic compounds, and particulate matter (14, 15). Globally, use of solid fuels may contribute to over 3.5 million premature deaths and 110 million disability-adjusted life years every year (16).

Indoor air pollution from solid fuel use may play an important role in cognitive decline. As compared with combustion of clean fuel, combustion of solid fuels releases higher levels of gaseous pollutants (such as PM2.5 particles, nitrogen oxides, and ozone), which may affect cognition function by increasing white matter hyperintensity volume and total cerebral brain volume, and may affect neurological disorders via oxidative stress and neuro-inflammation (8, 17). Although strong evidence links indoor air pollution exposure to higher risk of chronic diseases, low birth weight, and stillbirth (14), the effects of indoor air pollution from solid fuel use on cognition have not been well elaborated. Furthermore, certain subgroups may respond more strongly to indoor air pollution from solid fuel use, such as individuals who are female, aged 65 years and above, have low educational attainment, or have chronic diseases (18).

China is known not only for its heavy reliance on solid fuel use (around 450 million users in the country), but also for the highest prevalence of cognitive impairment globally, affecting around 9% of older persons in 2011 (19, 20). Therefore, research on the role of indoor air pollution from solid fuel use in cognitive decline is imperative to protect the mental health of at-risk Chinese adults. Our study aimed to explore the relationship between solid fuel use (a proxy for indoor air pollution) and cognitive function among middle-aged and older adults by analyzing a nationally representative longitudinal data. Furthermore, we examined whether age, sex, education, urban/rural residence, and chronic diseases could modify this association. Our study may provide insights into the role of indoor air pollution in mental health decline and help guide future measures to prevent cognitive impairment.

Methods

Data source

This study used longitudinal data from the China Health and Retirement Longitudinal Study (CHARLS), which started in 2011 and is conducted every two years. Data can be accessed through its official website (charls.ccer.edu.cn/en). CHARLS is a nationally representative population-based survey and was implemented by the National School of Development at Peking University. The survey includes information on household demographics, health status, health care utilization, and insurance, among many other variables. A multistage, stratified sampling strategy was used to select 17,708 individuals in 10,257 families from 150 counties of 28 provinces at the baseline survey in 2011. Subsequent biennial follow-ups were conducted from 2013 to 2015. From wave 2011 to wave 2013, 441 participants died and 2,081 were lost to follow up, and 15,186 individuals were re-interviewed in 2013. Of those individuals, 498 participants died and 1,123 were lost to follow up from wave 2013 to wave 2015, and 13,565 people were finally re-interviewed in 2015. Additional details on study design regarding sampling, response rates, and data quality assessment have previously been published (21).

From the waves in 2011-2015, 39,428 observations had information on cognitive function (Figure 1). From these data, we excluded 501 cases without information on household fuel solid use and excluded 1,057 cases with missing chronic diseases information.

The final analysis sample included 37,870 observations.

Ethical approval

The ethics application for collecting data on human subjects in CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015).

Measurement

Assessment of cognitive functions

This study examined two composite measurements of cognitive functions: mental status and episodic memory. These two well-established measurements combine individual test scores to assess cognitive functions (22). Mental status describes one's orientation and numerical, visual, and spatial abilities, while episodic memory represents one's memory for autobiographical events, which is captured by individuals' delayed memory and short term memory (22).

First, mental status was assessed by two cognitive tests, Telephone Interview of Cognitive Status (TICS) and figure drawing test. TICS included ten questions, from the awareness of the date, day of the week, and season of the year, to serial 7 subtraction from 100 (up to five times). The number of correct answers equals the TICS score, ranging from 0 to 10. The figure drawing test assessed the respondent's visual and spatial abilities. Interviewers showed participants a picture of two overlapping pentagons and asked them to draw and replicate the picture on paper. Respondents who successfully reproduced a similar picture received 1 point, and those who failed to do so received 0 points. The final score of mental status was calculated by adding the sum scores from TICS and the figure drawing test, with a range of 0 to 11.

Second, episodic memory was measured by using immediate and delayed word recall tasks. Participants were asked to repeat as many words as they could from a list of 10 Chinese nouns given by interviewers (immediate word recall) and to recall those words five minutes later (delayed recall). The score of episodic memory was calculated by averaging the number of words correctly repeated during immediate recall and delayed recall, with a range of 0 to 10.

To assess overall cognitive functions, we defined global cognition as the total score of episodic memory and mental status on a scale from 0 to 21, with a higher score indicating better cognitive functions.

Assessment of indoor air pollution

Across all three waves, indoor air pollution was determined by whether a respondent used solid fuel for cooking. Fuel types in CHARLS were categorized as clean fuel and solid fuel. Clean fuel included liquefied gas, natural gas, and electricity; solid fuel included coal, biomass charcoal, wood, and straw.

Measurement of covariates

We included demographic characteristics, including age (continuous variable), sex (male/female), residential area (urban/rural), and marital status (unmarried/married), as covariates in this study. Urban and rural areas were defined according to the 2013 urban and rural statistical division codes from the National Bureau of Statistics of China (23), which is nationally representative of both types of urban and rural areas in China (24). Because previous studies link cognitive impairment with education level (25), health behaviors such as smoking and drinking (26), obesity (27), and chronic diseases such as diabetes (28), lung disease (29), and cardiovascular disease (30), we also included those variables as covariates. Education level was categorized into two groups: primary school and below, and junior high school and above. Health behavior variables were measured as current use of tobacco or alcohol (yes/no). Obesity was determined by body mass index (BMI). BMI was defined as weight in kilograms divided by height in meters squared, and BMI $\geq$ 28 was categorized as obese (31). Chronic disease status was self-reported and included diabetes (yes/no), lung disease (yes/no), and cardiovascular disease (yes/no).

Statistical analysis

Descriptive statistics were calculated to describe the characteristics of participants and their cognitive function status. Continuous variables were presented as mean and standard deviation (SD), and categorical variables were summarized with counts and percentage. Linear mixed effect models were applied to examine the relationship between solid fuel use (indoor air pollution) and cognitive function. All models were adjusted by age, sex, residence, marital status, education, smoking, drinking, obesity, diabetes, lung diseases, and cardiovascular diseases. To test for potential moderating effects (whether there are differences in the association between indoor air pollution from solid fuel use and cognitive function in different groups) this study estimated the respective interactions between solid fuel use and sex, age, education level, and chronic diseases. Stata 14.0 (Stata Corp LLC, College Station, Texas, US) was used for all analyses, and statistical significance was defined as two-tailed P values less than 0.05.

Results

Characteristics of participants

Table 1 presents participant characteristics. Among all participants, 52.31% were female, and the mean age was 60.30 years (SD=9.26). Over 60% of the sample lived in rural areas, and 66.44% were in the education category of primary school and below. The average scores of global cognition, mental status, and episodic memory were 9.67 (SD=4.13), 6.25 (SD=3.02), and 3.42 (SD=1.80), respectively. Household solid fuel users made up 49.71% of participants, but this proportion was far more common among those living in rural areas (64.22%). Moreover, solid fuel users were more likely to have lower educational level, be current smokers, and suffer from lung diseases.

Cognitive function of participants

Compared with clean fuel users, solid fuel users had worse cognitive function. Solid fuel users on average scored 1.88, 1.32, and 0.56 lower on global cognition, mental status, and episodic memory, respectively (Table 2). Higher average scores of cognitive function were found in males, urban residents, those who were married, and those with higher education level, as compared with their counterparts.

The association between indoor air pollution and cognitive function

Table 3 describes the relationship between solid fuel use and cognitive function. In the linear mixed models, all three measures of cognitive functions were higher in clean fuel users than in solid fuel users. Compared with clean fuel users, solid fuel users had average global cognition scores that were 0.20 standard deviations lower, with a coefficient of -0.81 (95% CI:

-0.89, -0.73) (Appendix Table 2). Solid fuel users also had average mental status scores that were 0.21 standard deviations lower (coefficient = -0.63, 95% CI: -0.69, -0.57) and average episodic memory scores that were 0.10 standard deviations lower (coefficient = -0.16, 95% CI: -0.22, -0.14) than clean fuel users.

Table 4 summarizes the results of the interactions between cooking fuel type and demographic factors and chronic diseases. We found that the association between solid fuel use and global cognition was stronger among females, adults aged 65 years old and above, rural residents, and those in education level group of primary school and below, as compared with their counterparts. Moreover, global cognition of participants with cardiovascular diseases were more likely to be affected by solid fuel use than those without cardiovascular diseases. Similar patterns were found in mental status scores among different subgroups categorized by sex, age, residency, educational level, and cardiovascular disease. However, for the association between solid fuel use and episodic memory scores, there appeared to be a stronger effect in the education level group of junior high school and above, females and rural residents, while no significant difference was found between older and middle-aged adults.

Discussion

Our findings suggest that exposure to indoor air pollution measured by use of solid fuels was significantly associated with decreased mental status and episodic memory among the middle-aged and older population in China. The associations remained significant after adjusting for covariates. Our study combined multiple years of a nationally representative longitudinal data set to provide insights into the role of indoor air pollution in mental health decline. We also examined whether age, sex, education, residence and chronic diseases could modify these associations.

We found that using solid fuels in the household was related to a decrease in 0.79 points of global cognition. Our results are consistent with prior epidemiological studies on indoor air pollution and cognitive function, though there may be some limitations on comparability due to differing study designs and measurements of cognitive function. A cross-sectional study from Mexico suggested that scores of cognitive function (i.e. verbal learning, attention, verbal fluency, and orientation) were lower in solid fuel users than in clean fuel users, with coefficients ranging from -0.12 (95% CI: -0.17, -0.07) to -3.27 (95% CI: -4.09, -2.44) (11). Another cross-sectional study from India used the Mini-Mental State Examination to assess cognitive impairment and found that indoor air pollution exposure more than doubled the risk of developing cognitive impairment (12). Our results were also consistent with studies about the potentially harmful effects of solid fuel air pollution exposure on physical health (19) and other mental health outcomes (18).

The findings from our study indicated a sex difference in cognitive decline in response to indoor air pollution exposure. This result is similar to that of previous research, which suggested that cognitive functions of females may be more susceptible to hazardous effects of indoor particulate matter due to differences in sex hormones and neuroimmune responses to toxins (33). In addition, because females in many cultures are primarily responsible for cooking and other domestic work, they are most likely to be exposed to indoor air pollution (34). Our analyses found that older adults responded more strongly to the hazardous effects of indoor air pollution, which is similar to the results found by another study in China (10). As individuals age, their brains may become more susceptible to indoor air pollution or may have accumulated longer exposures to indoor air pollution, which may explain the differences by age. Moreover, our study suggested that individuals with low educational attainment were more susceptible to impaired cognitive control related to solid fuel air pollution exposure. The reason for this finding may be that participants with high education level have more knowledge to protect themselves from potentially harmful effects from indoor air pollution, therefore engaging in behaviors such as installing air purifiers to reduce indoor air pollutants (18). Individuals with high education level may also be more likely to reside in localities with lower indoor air pollution, which may explain the differences by education. Lastly, cardiovascular diseases may serve as a possible moderating variable of the association between indoor air pollution and cognitive decline. Strong evidence suggests that indoor air pollutants are associated with cardiovascular and respiratory diseases (19), which may impact amyloid-beta (Aβ) deposits in the brain (35) and subsequently result in cognitive disorders (36).

The major strengths of this study include the use of data from a nationally representative longitudinal survey in China. Compared to a previous Chinese study on the relationship between indoor air pollution and cognitive function (32), our study has combined multiple years of CHARLS data to increase statistical power. However, our study is still not without limitations. First, due to database restrictions, this study had to use the dichotomous variable of using/not using solid fuel combustion for cooking as a proxy variable for indoor air pollutants, instead of direct measurements of personal exposure to indoor air pollution. Therefore, the results should be interpreted with caution. Second, while missing data may be inevitable in a large, national study (Appendix Table 1), the exclusion of samples with incomplete information from our analyses may introduce selection bias. Third, although we have already controlled for demographic characteristics, health behaviors, and chronic diseases, some variables such as genetic variables could not be included in this study, which may confound the results. Fourth, due to limitations of the cognitive function assessment, we could not differentiate levels of cognitive function to identify specific cognitive impairments. Future studies should further investigate the relationship between different levels of cognitive function and indoor air pollution.

Conclusions

Exposure to indoor air pollution as measured by solid fuel use was significantly associated with decreased cognitive function among middle-aged and older adults in China. Females, older adults, those with lower education level, and those with cardiovascular diseases responded more strongly to the hazardous effects of indoor air pollution. These results support the role of indoor air pollution in neurobehavioral disorders in the Chinese population. Certain preventative measures may be crucial for slowing cognitive decline and protecting mental health among adults. These practices could include expanding the use of improved cookstoves and clean fuel (e.g. liquefied petroleum gas, nature gas, and renewable energy resources) in households to significantly reduce air pollutant emissions. The exposure-response relationships found between indoor air pollution measured by solid fuel use and cognitive function in this study may help guide the design of policies to reduce indoor air pollution and may suggest potential health benefits of reducing air pollution through clean cookstove interventions.

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Conflicts of Interest

The authors declare no conflicts of interest.

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Conflicts of Interest

The authors would like to thank all co-workers. We would also like to extend our thanks to the invaluable contributions by the study participants and data collection staff.

Credit author statement: Yanan Luo: study concept and design, drafting the manuscript, data analysis, interpretation and revision of article. Yijin Zhong, Lihua Pang and Yihao Zhao: revision of article. Xiaoying Zheng: critical revision of article for important intellectual content. All authors gave final approval of the version to be published.

Figure 1 Flowchart of sampling of this study

Table 1 Characteristics of participants (N=37,870)

Characteristics	Total	Clean fuel users	Solid fuel users
Age, years	60.30 (9.26)	59.61 (9.24)	60.99 (9.24)
Sex			
Female	19,648 (51.88)	9,879 (51.88)	9,769 (51.89)
Male	18,222 (48.12)	9,164 (48.12)	9,058 (48.11)
Residence			
Urban	14,545 (38.41)	10,697 (56.17)	478 (2.54)
Rural	23,325 (61.59)	8,346 (43.83)	18,166 (96.49)
Marital status			
Unmarried	746 (1.97)	268 (1.41)	478 (2.54)
Married	36,540 (96.49)	18,374 (96.49)	18,166 (96.49)
Missing	584 (1.54)	401 (2.11)	183 (0.97)
Education			
Junior high school and above	12,710 (33.56)	8,374 (43.97)	4,336 (23.03)
Primary school and below	25,159 (66.44)	10,668 (56.02)	14,491 (76.97)
Missing	1 (0.00)	1 (0.01)	0 (0.00)
Smoking			
No	25,792 (68.11)	13,273 (69.7)	12,519 (66.49)
Yes	9,012 (23.8)	4,228 (22.2)	4,784 (25.41)
Missing	3,066 (8.1)	1,542 (8.1)	1,524 (8.09)
Drinking			
No	25,117 (66.32)	12,472 (65.49)	12,645 (67.16)
Yes	12,733 (33.62)	6,559 (34.44)	6,174 (32.79)
Missing	20 (0.05)	12 (0.06)	8 (0.04)
Obesity			
No	27,270 (72.01)	12,894 (67.71)	14,376 (76.36)
Yes	10,600 (27.99)	6,149 (32.29)	4,451 (23.64)
Diabetes			
No	34,681 (91.58)	17,209 (90.37)	17,472 (92.80)
Yes	3,189 (8.42)	1,834 (9.63)	1,355 (7.20)
Lung diseases			
No	32,989 (87.11)	16,837 (88.42)	16,152 (85.79)
Yes	4,881 (12.89)	2,206 (11.58)	2,675 (14.21)
Cardiovascular diseases			
No	31,927 (84.31)	16,007 (84.06)	15,920 (84.56)
Yes	5,943 (15.69)	3,036 (15.94)	2,907 (15.44)

Note: Age presented as mean (SD) and categorical variables presented as counts (%).

Table 2 Cognitive function of participants (N=37,870)

Characteristics	Global cognition	Mental status	Episodic memory
Fuel users			
Clean fuel users	10.60 (3.94)	6.91 (2.81)	3.69 (1.81)
Solid fuel users	8.72 (4.11)	5.59 (3.08)	3.13 (1.74)
Sex			
Female	8.86 (4.32)	5.52 (3.12)	3.34 (1.85)
Male	10.54 (3.72)	7.04 (2.69)	3.49 (1.73)
Residence			
Urban	10.85 (3.89)	7.07 (2.75)	3.77 (1.82)
Rural	8.93 (4.11)	5.74 (3.07)	3.19 (1.75)
Marital status			
Unmarried	7.89 (4.28)	5.08 (3.17)	2.8 (1.9)
Married	9.7 (4.12)	6.27 (3.01)	3.43 (1.79)
Missing	9.8 (4.32)	6.43 (3.01)	3.37 (1.89)
Education			
Junior high school and above	12.33 (2.97)	8.01 (2.10)	4.32 (1.64)
Primary school and below	8.32 (3.98)	5.36 (3.02)	2.96 (1.70)
Missing	15.00 (.)	10.00 (.)	5.00 (.)
Smoking			
No	9.40 (4.25)	6.01 (3.09)	3.40 (1.83)
Yes	10.19 (3.82)	6.77 (2.78)	3.42 (1.74)
Missing	10.35 (3.82)	6.79 (2.81)	3.55 (1.73)
Drinking			
No	9.24 (4.22)	5.92 (3.08)	3.32 (1.82)
Yes	10.50 (3.82)	6.90 (2.78)	3.60 (1.74)
Missing	9.30 (3.92)	5.60 (3.14)	3.70 (1.29)
Obesity			
No	9.56 (4.10)	6.20 (3.00)	3.36 (1.78)
Yes	9.94 (4.20)	6.38 (3.06)	3.56 (1.83)
Diabetes			
No	9.65 (4.14)	6.24 (3.02)	3.42 (1.80)
Yes	9.81 (4.07)	6.42 (2.99)	3.40 (1.74)
Lung diseases			
No	9.74 (4.13)	6.29 (3.02)	3.45 (1.80)
Yes	9.15 (4.08)	5.99 (3.02)	3.16 (1.76)
Cardiovascular diseases			
No	9.65 (4.13)	6.24 (3.02)	3.41 (1.80)
Yes	9.73 (4.15)	6.31 (3.04)	3.42 (1.80)

Note: Numbers presented as mean score (SD).

Table 3 Effect of household air pollution from solid fuel use on cognitive function of participants

Characteristics	Global cognition	Mental status	Episodic memory
Fuel users			
Clean fuel users	Reference	Reference	Reference
Solid fuel users	-0.81 (-0.89, -0.73)	-0.63 (-0.69, -0.57)	-0.18 (-0.22, -0.14)
Age, years	-0.10 (-0.11, -0.10)	-0.05 (-0.06, -0.05)	-0.05 (-0.05, -0.05)
Sex			
Female	Reference	Reference	Reference
Male	1.38 (1.28, 1.47)	1.35 (1.28, 1.42)	0.03 (-0.02, 0.07)
Residence			
Urban	Reference	Reference	Reference
Rural	-1.03 (-1.11, -0.94)	-0.74 (-0.80, -0.67)	-0.29 (-0.33, -0.25)
Marital status			
Unmarried	Reference	Reference	Reference
Married	0.94 (0.68, 1.20)	0.73 (0.53, 0.92)	0.21 (0.09, 0.34)
Education			
Junior high school and above	Reference	Reference	Reference
Primary school and below	-2.74 (-2.83, -2.65)	-1.78 (-1.84, -1.71)	-0.96 (-1.01, -0.92)
Smoking			
No	Reference	Reference	Reference
Yes	-0.23 (-0.33, -0.13)	-0.15 (-0.23, -0.08)	-0.08 (-0.12, -0.03)
Drinking			
No	Reference	Reference	Reference
Yes	0.18 (0.09, 0.27)	0.09 (0.03, 0.16)	0.09 (0.04, 0.13)
Obesity			
No	Reference	Reference	Reference
Yes	-0.13 (-0.22, -0.05)	-0.13 (-0.19, -0.07)	0.00 (-0.04, 0.04)
Diabetes			
No	Reference	Reference	Reference
Yes	0.10 (-0.03, 0.23)	0.13 (0.03, 0.23)	-0.03 (-0.09, 0.03)
Lung diseases			
No	Reference	Reference	Reference
Yes	-0.14 (-0.26, -0.03)	-0.09 (-0.17, -0.01)	-0.05 (-0.11, 0.00)
Cardiovascular diseases			
No	Reference	Reference	Reference
Yes	0.38 (0.28, 0.48)	0.24 (0.17, 0.32)	0.14 (0.09, 0.18)

Note: Numbers presented as coefficient (95% CI).

Table 4 Heterogeneous effects of household solid fuel use on cognitive function, by demographic factors, health behaviors, and chronic diseases

Characteristics	Global cognition	Mental status	Episodic memory
Demographic factors			
Sex			
Male × solid fuel users	0.74 (0.59, 0.89)	0.61 (0.50, 0.72)	0.13 (0.06, 0.20)
Age group			
≥65 years old × solid fuel users	-0.41 (-0.57, -0.25)	-0.34 (-0.46, -0.21)	-0.07 (-0.15, 0.00)
Residential area			
Urban × solid fuel users	0.54 (0.37, 0.71)	0.53 (0.40, 0.66)	0.40 (0.32, 0.48)
Education level			
Primary school and below × solid fuel users	-0.21 (-0.37, -0.04)	-0.29 (-0.41, -0.17)	0.17 (0.09, 0.24)
Chronic diseases			
Diabetes			
Diabetes × solid fuel users	-0.05 (-0.34, 0.23)	0.02 (-0.19, 0.23)	-0.08 (-0.20, 0.05)
Lung diseases			
Lung diseases × solid fuel users	0.10 (-0.13, 0.34)	0.08 (-0.10, 0.25)	0.02 (-0.08, 0.13)
Cardiovascular diseases			
Cardiovascular diseases ×solid fuel users	-0.36 (-0.57, -0.15)	-0.23 (-0.39, -0.07)	-0.13 (-0.22, -0.03)

Note: Numbers presented as coefficient (95% CI); all models were adjusted by age, sex, residence, marital status, education, smoking drinking, obesity, diabetes, lung diseases and cardiovascular diseases.

Highlights

1. Although studies focused on the role of outdoor air pollution on cognitive function, very few of them regard how air pollution from indoor sources associates with cognition.
2. China is not only known for highly relying on solid fuel use (around 450 million persons), but also for the highest prevalence of cognitive impairment globally, which affects around 9% of older persons in 2011. Exploration of the role of indoor air pollution from solid fuel use on cognitive function is imperative.
3. Exposure to indoor air pollution from solid fuel use had a significant effect on cognitive decline among middle-aged and older adults in China.
4. Females, older adults, lower education level groups, and participants with cardiovascular diseases responded more strongly to the hazardous effects of indoor air pollution.
5. These results gave the support for the role of indoor air pollution in neurobehavioral disorders in Chinese population. Promotion and dissemination of expanding the use of clean fuel (eg. liquefied petroleum gas, nature gas and renewable energy resources) in household and improved cookstoves may significantly reduce emissions, and be crucial for mental health protection.

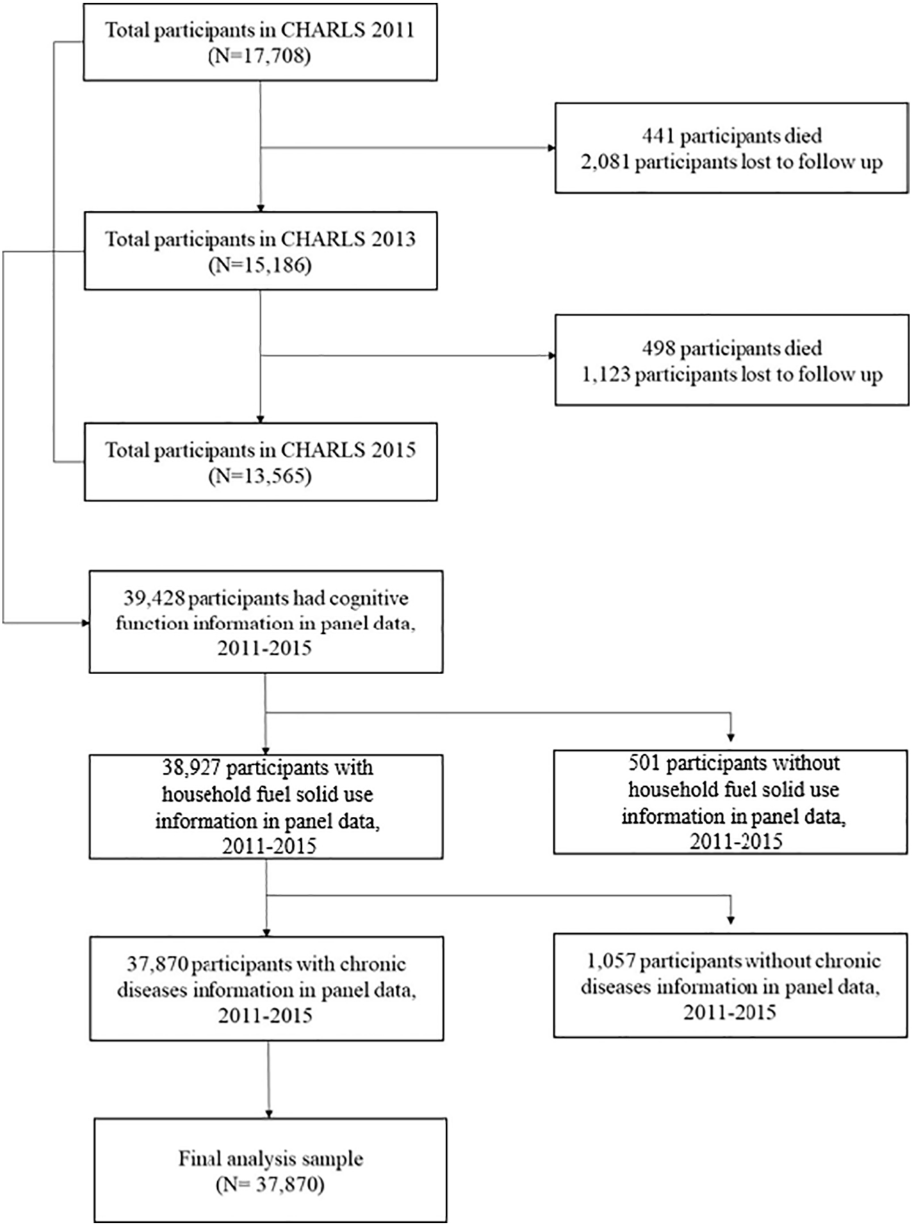
Total participants in CHARLS 2011 (N=17,708)
441 participants died
2,081 participants lost to follow up
Total participants in CHARLS 2013 (N=15,186)
498 participants died
1,123 participants lost to follow up
Total participants in CHARLS 2015 (N=13,565)
39,428 participants had cognitive function information in panel data, 2011-2015
38,927 participants with household fuel solid use information in panel data, 2011-2015
501 participants without household fuel solid use information in panel data, 2011-2015
37,870 participants with chronic diseases information in panel data, 2011-2015
1,057 participants without chronic diseases information in panel data, 2011-2015
Final analysis sample (N= 37,870)

Figure 1