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January 2020

Solid Fuel-Related Indoor Air Pollution And Poor Sleep Quality In Adults Aged 45 Years And Older; A National Longitudinal Study In China

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Solid fuel-related indoor air pollution and poor sleep quality in adults aged 45 years and older; a national longitudinal study in China

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Year Completed: 2020

Year Degree Awarded: 2020

Degree Awarded: Master of Public Health

Department: School of Public Health

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Abstract

Background: Sleep disorders are a common public health issue in an aging society. Outdoor air pollution has been linked to poor sleep quality, but few studies have investigated the relationship between indoor air pollution derived from solid fuel combustion and sleep quality in elderly.

Objective: To evaluate the association between indoor air pollution due to cooking solid fuels and sleep quality among adults aged 45 years and elderly in China.

Methods: We analyzed data from the China Health and Retirement Survey (CHARLS), a national survey of ~17,000 residents aged over 45 from 150 counties/districts in China. Participants were restricted to those who completed waves of CHARLS in 2011, 2013, and 2015 (n=8,668). Sleep quality was indicated by self-reported average sleep duration (hours/night) and the numbers of restless days in per week in the 2015 survey. Participants also reported household cooking fuel type in all three surveys. We compared the “solid fuels”, primarily including coal, crop residue or wood burning, with the “clean fuels” including electric, natural gas, and liquefied petroleum gas as the reference. We also evaluated the years of solid fuel use (0, 1-4 or ≥5 years). We used multinomial logistic regression and estimated the odd ratios (OR) and 95% confidence interval (CI) for sleep duration (7-9 hours/night as the reference) and restless sleep (0 day as the reference) according to fuel types adjusting for potential confounding factors.

Results: Solid fuels use for 5 or more years was associated with a shorter duration of sleep (OR=1.17 95% CI 1.01, 1.35 for less than ≤6 hours/day) and higher frequencies of restless days of sleep (OR=1.33 95%CI 1.13, 1.56 for ≥more than 5 days/week) compared with clean fuels users. The associations were in the similar direction but smaller in magnitude for solid fuels use in 1-4 years.

Conclusions: Primary cooking fuel was associated with poor sleep quality in an elderly Chinese population. Further research is needed to evaluate of the specific type of fuels and indoor air pollutants to inform intervention strategies.

Acknowledgements

I would like to express my deepest gratitude to my thesis readers Professor Dr. Zeyan Liew and Professor Dr. Krystal J. Godri Pollitt. I'm really grateful to Dr. Liew for his constant encouragement and patient guidance during my study life in Yale. I learnt a lot from every discussion and was encouraged by his intelligence and passion on research. I would also like to express my sincere gratitude to Jiajun Luo for his help and valuable advice during the writing of this thesis.

I would also like to sincerely thank my parents and dear friends for their warm love all the time and great patience during my completion of the thesis.

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Introduction

Sleep disorders have been a major public health issue in an aging society, since the elderly are susceptible to age-related changes in circadian rhythm and sleep cycles (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). Early awakening and more fragmented sleep, and a decrease in sleep efficiency were more commonly reported in adults 60 years and older (Suzuki, Miyamoto, & Hirata, 2017). Sleep disorders and poor sleep quality have been associated with a broad range of adverse health outcomes including cardiovascular disease, hypertension, stroke, cognitive impairment, depression, etc. (Bathgate & Fernandez-Mendoza, 2018; Buxton & Marcelli, 2010; Maung, El Sara, Chapman, Cohen, & Cukor, 2016; Vandeputte & de Weerd, 2003; Yu et al., 2018).

A variety of physical and psycho-social risk factors have been identified for sleep disorder, including noise (Halonen et al., 2012; Nassur et al., 2019), artificial light at night (Cho et al., 2015; Obayashi, Saeki, & Kurumatani, 2014), life habits like lack of exercise and smoking (Passos et al., 2011; Wetter & Young, 1994), psychological factors like job stress and depression (Kalimo, Tenkanen, Härmä, Poppius, & Heinsalmi, 2000; Nutt, Wilson, & Paterson, 2008). In terms of environmental or household exposures, artificial light at night and noise pollutions are typical environmental concerns disturbing sleep. Artificial light can suppress the secretion of melatonin. Continuous nighttime traffic noise can make people wake up more frequently during sleep and affect deep sleep. Accumulating evidence has also suggested that exposures to ambient air pollution, including particulate matter (PM_{10},

$PM_{2.5}$), sulfur dioxide, nitrogen oxide, carbon monoxide and polycyclic aromatic hydrocarbons (PAHs), are associated with poor sleep quality. Ambient air pollution includes outdoor and indoor air pollution. Some studies have shown the effect of outdoor air pollution on sleep quality. A large cross-sectional study in Northeastern China of 59754 children aged 2–17 years found that sleep disorder assessed by Sleep Disturbance Scale for Children (SDSC) was generally associated with outdoor air pollutants including PM_1, $PM_{2.5}$, NO_2, SO_2, O_3 and CO, especially in female (Lawrence et al., 2018). A Chinese study in Ningbo province found exposures to multiple outdoor air pollutants, including NO_2, SO_2, O_3, $PM_{2.5}$ and PM_{10}, were associated with hospital visits for sleep disorders among 395,651 elderly Chinese (M. Tang et al., 2020). A cross-sectional study in seven U.S. urban areas between 1995 and 1998, including 6441 participants over 39, explored the effect of variation in outdoor PM_{10} and also found that the decrease in sleep efficiency was associated with increases in short-term variation in PM_{10} (Zanobetti et al., 2010). Therefore, sleep quality can be affected by ambient air pollution containing PM, NO_2, SO_2, O_3, etc.

Today people spend nearly 70% time indoors and the value is higher among the elderly (Almeida-Silva, Wolterbeek, & Almeida, 2014; Klepeis et al., 2001) and thus indoor air is considered to have an important impacts on our health, especially in rural areas because of the use of solid fuels. Kitchen activities are major sources of indoor air pollution because pollutants such as particulate matter, NO_2, SO_2 and others can be created from fuel combustion during the process of cooking (He et al., 2004). The use of solid fuels (including wood, biomass, coal and dung) in open fires and inefficient stoves exacerbate the indoor air pollution. At present, about 3 billion people are estimated to cook in such inefficient ways globally because of bad financial situation and most of them live in low- or middle-income countries (WHO, 2018). Studies have found that the use of solid fuels is associated with many adverse health outcomes. For example, a cohort study between 1989 and 2011 based on the data of China Health and Nutrition Survey (CHNS) found that the prevalence of respiratory diseases was higher and self-assessed health level was lower among solid fuel users (Liao, Tang, & Wei, 2016) . Studies have also found the use of solid fuels is associated with other chronic diseases like lung cancer, cardiovascular disease and hypertension (Lee et al., 2012; Li et al., 2020; Raspanti et al., 2016). And the use of solid fuel was found to have adverse effect on cognitive function and depression (Liu, Chen, & Yan, 2019; Saenz, Wong, & Ailshire, 2018; Zanobetti et al., 2010). However, limited studies have investigated the relationship between indoor air pollution derived from solid fuel combustion and sleep quality directly, especially in the elderly. There are two studies in Peru indicating that the reduction of solid fuel pollution improved sleep symptoms in children aged under fifteen by using less environmentally contaminating kitchen stoves (Accinelli et al., 2014; Castañeda, Kheirandish - Gozal, Gozal, Accinelli, & Group, 2013). More studies are still needed in this area.

According to a large sampling survey of China among 512,891 adults from 10 areas during 2004-2008, there were about 52% participants using coals or charcoal for cooking or heating, and solid fuel use was more prevalent in rural areas than urban areas (Li et al., 2018). In addition, aging population is rapidly growing in China. The Chinese population aged 65 and older has reached 24.9 million and made up 17.9% of the total population in 2018 (Xinhua News, 2019). A cross-sectional study surveyed 2416 rural elderly aged over 60 in Anhui Province, China, indicated that about half of participants self-reported poor sleep quality during the period of 2009–2010 (Li et al., 2018). Within this context, we conducted a study to evaluate the association between household use of solid fuel and sleep quality using a representative sample of residents ages 45 and older in China. We hypothesized that indoor air pollution due to household use of solid fuel affect poor sleep quality in Chinese elderly.

2 Methods

2.1 Data source

The data we used were from the China Health and Retirement Longitudinal Study (CHARLS, http://charls.pku.edu.cn/zh-CN), a nationally representative longitudinal survey of ~17,000 Chinese residents ages 45 and older (CHARLS, 2019). It was launched by Peking University in 2011 and collected data in 150 counties/districts and 450 villages/resident committees across the whole China every two years (in 2011, 2013 and 2015). Participants were instructed to fill out the questionnaires in person. Only participants who completed the all three waves of CHARLS surveys in 2011, 2013, and 2015 were eligible for this study (N=9484). After excluding those with brain damage or mental retardation and with emotional, nervous, or psychiatric problems (N=816), the final sample size was 8,668.

2.2 Sleep quality data

Sleep quality was assessed using self-reported average sleep duration (hours/night) and the numbers of restless days in per week in the 2015 survey. Participants were asked two questions: (1) During the past month, how many hours of actual sleep did you get at night (average hours for one night)? (2) How many days were in accord with the state of "my sleep was restless"?. Average sleep hours were classified into: severe insufficient sleep (<6 hours/night), mild insufficient sleep (6-7 hours/night), sufficient sleep (7-9 hours/night as the reference) and excessive sleep (>9 hours/night). The number of restless days were classified into rarely or none of the time (< 1 day), some or a little of the time (1-2 days), occasionally or a moderate amount of the time (3-4 days), and most or all of the time (5-7 days).

2.3 Solid fuel-related indoor air pollution data

In all three CHARLS surveys from 2011 to 2015, participants were asked: What is the main source of cooking fuel? Coal, crop residue/wood burning was classified as solid fuels, and liquefied petroleum gas, natural gas, marsh gas and electricity were classified as clean fuels. Using the responses from all three CHARLS surveys, we calculated the duration of solid fuels use prior to outcome assessment, as ≥5 years if reported usage in all three waves since 2011 or 1-4 years if usage was reported in one or two waves of the surveys. We also identified clean fuel user and solid fuel user based on whether ever used solid fuels during three waves. And we use a continuous predictor to test for trend. We assumed each wave covered two years and coded non-users, those reported use in only one wave, those reported use in two waves and those reported use in three waves as zero, one, three and five (the conservative years they used solid fuels) to see the trend.

2.4 Statistical analysis

We conducted multinomial logistic regression to estimate odd ratio (OR) and 95% confidence interval (CI) for sleep duration or restless sleep according to years of solid fuel usage for cooking adjusting for potential confounding factors.

Potential confounders were selected based on literature review considering factors associated with choices of cooking fuel use and sleep quality and data availability in CHARLS. In all analyses, we adjusted for gender (male, female), age (45-65 or >65 years), living place (urban or rural area), household economic level (measured by household expenditure in last year), education level (less than high school, high school, college degree or higher), marriage status (living with couple or living alone), smoking habits (active and passive smoking) and cooking location (whether has a kitchen outside the living room). Urban or rural area was classified based on the codes of National Bureau of Statistics of China with rural-urban fringes and villages included in the urban area. Household economic level was measured by overall household expenditure in the last year (2014), including clothing and bedding, traveling expenses, centrally heated fees, durable goods and electronics, education and medical expenditure, etc. Considering that there was no direct data of exact individual income and household income in CHARLS database, household expenditure is a reasonable measure for household economic levels, which has also been discussed and applied in past research (Shi & Zhang, 2013; Strauss & Thomas, 2007). Marital and cohabitation, married with living with spouse or cohabitated, or others including never married, separated, divorce, widowed or living alone. Individual smoking habit was classified as never, former and current smoking. Secondhand smoke was measured by whether other family members of non-smokers have smoking habit. For all nominal variables with multiple levels, we used dummy variables in the model.

Besides above analysis, considering that older people are more vulnerable to air pollutants exposure and women are more likely to responsible for cooking in Chinese families, we also stratified data by age and gender to see whether the outcomes were different. And we estimated odd ratios for both solid fuel users and long-term users. Here long-term users were those used solid fuels for 5 or more years. Solid fuel users were all participants who ever used solid fuels and thus contained long-term users.

3 Results

3.1 Summary of selected study characteristics

In this population, 35.4% (N=3064) participants reported never using solid fuel, 33.8% (N=2933) using solid fuels for 1-4 years, 30.8% (N=2671) using solid fuel for ≥5 years. The selected characteristics of the study population by solid fuel use groups are summarized in Table 1. Participants with a long duration of solid fuels use were more likely to have a higher age, lower household expenditure and lower educational level. And participants living in rural areas were more likely to use solid fuels. More than 90% of participants had a kitchen outside the living room in their houses but those living in rural areas were more likely not.

3.2 Associations of years of solid fuel use with sleep quality

The results were shown in Table 2. When considering solid fuel users and clean fuel users, solid fuel users had 29% higher odds (95% CI: 1.29, 1.48) for more than 5 restless days/week compared with clean fuels users.

When considering the years of using solid fuels during three waves, for sleep duration, solid fuels use for 5 or more years was associated with a shorter duration of sleep. We estimated that solid fuel users had 17% higher odds (95% CI: 1.01, 1.35) for sleep time less than 6 hours/day compared with clean fuels users. For restless days of sleep, solid fuels use for 5 or more years was also associated with higher frequencies of restless days of sleep. The odd ratios were 1.33 (95% CI: 1.13, 1.56) for more than 5 restless days/week and 1.28 (95%CI: 1.07, 1.53) for 3-4 days/week. The associations were in the similar direction but smaller in magnitude for solid fuels use in 1-4 years. The odd ratio was 1.26 (95%CI: 1.08, 1.47) for more than 5 restless days/week.

For duration trend, the results showed that increasing in solid fuel use by each one year increases the odds for more than 5 restless days/week by 3.5% (95%CI: 1.00, 1.07) and increases the odds for 3-5 restless days/week by 5.4% (95%CI: 1.02, 1.09).

3.3 Associations of years of solid fuel use with sleep quality stratified by age and gender

The results after stratifying were shown in Table 3 and 4. Among two age groups, for sleep duration, the odd ratio of long-term users aged more than 65 years old was 1.63 (95% CI: 1.11, 2.42) for sleep time more than 9 hours/day while the odd ratio of long-term users group aged 45-65 was 1.08 (95% CI: 0.82, 1.43). For restless days of sleep, participants aged more than 65 had higher odd ratios compared with those aged between 45 to 65. The odd ratios were 1.63 (95% CI: 1.24, 2.13) for more than 5 restless days/week among solid fuel users and 1.68 (95% CI: 1.24, 2.27) for long-term users in older group while the odd ratios were 1.18 (95% CI: 1.01, 1.39) for more than 5 restless days/week among solid fuel users and 1.22 (95% CI: 1.01, 2.48) for long-term users in group aged 45-65.

Among gender groups, for sleep duration, the odd ratio of male long-term users aged was 1.39 (95% CI: 1.01, 1.91) for sleep time more than 9 hours/day while the odd ratio of female long-term users was 1.10 (95% CI: 0.81, 1.50). For restless days of sleep, female had higher odd ratios compared with male. The odd ratios were 1.38 (95% CI: 1.15, 1.66) for more than 5 restless days/week among female solid fuel users and 1.47

(95% CI: 1.18, 1.82) among female long-term users while the odd ratios were 1.18 (95% CI: 0.96, 1.46) for more than 5 restless days/week among male solid fuel users and 1.16 (95% CI: 0.90, 1.48) among male long-term users.

4 Discussion

To our knowledge, there were few studies estimating the association between indoor air pollution from solid fuel use and sleep quality in elderly based on a large nationally representative database of China with high proportion of household using solid fuel for cooking. Household solid fuel use is the main pollutant source of indoor air pollution in developing areas (WHO, 2018). And there were about 170 million urban residents and 490 million rural residents using solid fuels for cooking in China in 2010 based on population census data (X. Tang & Liao, 2014). Therefore, the health effect of the use of solid fuel has become an important issue.

Our findings indicate that solid fuels use for cooking was associated with a shorter duration of sleep and higher frequencies of restless days of sleep. The associations were stronger for participants reported solid fuels for ≥ 5 years than those who indicated usage for 1-4 years using the three surveys prior to the outcome assessment. Our findings suggest that long-term exposure could affect sleep duration and disturbance. Moreover, switching from solid to clean fuels might mitigate the adverse effect of solid fuel use.

The effect of using solid fuels on sleep has been investigated in some prior studies, but the sample sizes were smaller and more only focused on children. Two studies in Peru indicated that the reduction of solid fuel pollution improved sleep symptoms of sleep apnea and respiratory related symptoms in children who faced long-term exposure to biomass fuel indoor pollution by using less environmentally contaminating kitchen stoves (Accinelli et al., 2014; Castañeda, Kheirandish-Gozal, Gozal, Accinelli, & Group, 2013). The sample sizes were 82 and 59 separately. Another cross-sectional study in China suggests that outdoor exposures to $PM_{2.5}$, PM_{10} and NO_2, measured by satellite data, are associated with poor sleep quality characterized by Pittsburgh Sleep Quality Index (PSQI) among 39259 rural adults (Chen et al., 2019). The odd ratio of long-term exposure to $PM_{2.5}$ was 1.15 and long-term exposure to NO_2 was 1.14 in this study. Studies have shown indoor air pollutants could have some adverse effect on sleep quality. It's consistent with our results and our study could give some reference for the effect of solid fuel use on a large elderly population. But more research focusing on solid fuel use on sleep quality for the elderly should be given more attention.

Actually, the biological mechanism that how air pollution affects sleep quality is still not clear. Studies found that particulate matters could affect neurobehavioral functions in human and animal models (Calderón-Garcidueñas et al., 2002; Guxens & Sunyer, 2012; Wang et al., 2009) and then affect sleep quality. And long-term air pollutants exposure increases the risk of respiratory tract inflammation relative to sleep-disorder breathing (Calderón-Garcidueñas et al., 2007). Considering the complexity of mixture air pollution, the underlying mechanism can be complex.

Indoor air pollution has become a stressing public health issue, especially in rural areas in China coupled with an aging population with increasing burden for chronic diseases including sleep disorders and medical cares. We summarized the solid fuel types for cooking in three waves (Figure 1), which indicated that the proportions of participants using coal and crop residue or wood burning have decreased and the proportions of using natural gas and electric have been increased. However, the proportion of participants using crop residue or wood burning was still the largest. Many measures have been taken by the government and residents have been encouraged to use cleaner fuels like electric, natural gas, liquefied petroleum gas and cleaner coal instead of traditional solid fuels like coal, crop residue or wood burning. Recently, it was reported by over 6 million household in the North of China changed to use cleaner energy including electricity and natural gas in 2018 but mostly in urban or sub-urban areas (NRDC, 2019). Indoor air pollution derived from solid fuel use is still a threaten for residents especially in rural areas. Our findings support the current policy recommendations on moving from solid to clean fuel types for all residents in China. However, cleaner fuels may be not affordable for low income households alternative strategies such as installing new facilities for using natural gas or electricity, government subsidies may need to be explored.

Our studies have a number of strengths. First, we analyzed data from a large prospective study with three repeated surveys from representative sampling of 150 counties/districts in China, which contains main Chinese provinces and cities, covering about 17,000 residents. The longitudinal surveys also allowed us to evaluate duration of use, thus to capture the potential change from solid to clean fuel as the primary household cooking fuels. We also indicated the potential age and sex differences. Based on our results, we can see that solid fuel users aged over 65 are more likely to face worse outcome including excessive sleep duration and higher frequencies of feeling restless. Female solid fuel users are more likely to have higher frequencies of feeling restless while male solid fuel users are more likely to have excessive sleep duration.

Our study has several limitations. Firstly, we measured solid fuel-related indoor air pollution by the years of solid fuel use. But we didn't classify different kinds of clean fuels or solid fuels in more details. For example, natural gas may also cause the pollution of NOx, but it's considered much cleaner than traditional solid fuel use such as coal. Secondly, we did not consider other types of indoor and/or outdoor air pollutants measures which are not available from the CHARLS database. Thirdly, the data we used was primary cooking fuel without heating fuel because of missing data. Solid use for heating could be important source of indoor air pollution, especially for northern areas in winter. Considering the latitude of the cities, warm areas might not need heating as much. And the ways of heating supply also affect a lot, like whether use centralized heat supply. While solid fuel use for heating affects ambient air quality profoundly, except confounders we have considered, other unmeasurable variables may exist and can also affect our results. In our study, we didn't consider household income (We used household expenditure instead), nutrients, healthcare access to healthcare for other underlying psychological factors affecting sleep, etc.

5 Conclusion

In this cohort study based on the three waves of CHARLS from 2011-2015, we found that the years of solid fuel use was associated with poorer sleep quality measured by average sleep duration and the numbers of restless days in an Chinese adults 45 years and older. The results indicated using solid fuel for longer duration may be associated with insufficient or excessive sleep and higher frequencies of feeling restless for the elderly. Our findings suggest that it's essential to pay more attention to sleep quality of the elderly and solid fuel-related indoor air pollution, especially for the choice of fuels. More studies are needed for investigating the mechanism of indoor air pollution derived from solid fuel use, the specific type of fuels and solid fuel use for heating.

Table 1 Distribution of demographics characteristics

Characteristic	Years of solid fuel use: Solid fuel use for 0yr (3064)	Solid fuel use for 1-4yr(2933)	Solid fuel use for 5yr(2671)	missing	p-value
Age (years)	60.5 ± 8.7	61.6 ± 8.7	62.8±8.6	39	<.0001
45-65	2265 (74.3)	2010 (68.9)	1664 (62.5)		
Over 65	783 (25.7)	907 (31.1)	1000 (37.5)		
Gender				28	0.883
Male	1322 (48.4)	1270 (48.6)	1165 (49.1)		
Female	1420 (51.6)	1346 (51.4)	1209 (50.9)		
Area				0	<.0001
Rural	1003 (36.4)	1873 (71.5)	1993 (83.8)		
Urban	1755 (63.6)	746 (28.5)	385 (16.2)		
Expenditure (RMB)				115	<.0001
<=10,000	1845 (61.0)	2230 (77.1)	2115 (63.6)		
10,000-50,000	932 (30.8)	549 (19.0)	457 (17.3)		
50,000-100,000	128 (4.2)	69 (2.4)	42 (1.6)		
> 100,000	118 (3.9)	44 (1.5)	24 (0.9)		
Educational level				5	<.0001
No formal	754 (27.4)	1178 (45.0)	1282 (53.9)		
≤12 years	1872 (67.9)	1425 (54.5)	1083 (45.5)		
≥ 12 years	130 (4.7)	16 (0.6)	13 (0.6)		
Marital status				0	0.0003
Married	2353 (85.3)	2129 (81.3)	1997 (84.0)		
Not married	405 (14.7)	490 (18.7)	381 (16.0)		
Smoke				241	0.0012
Current	741 (27.6)	809 (31.8)	753 (32.6)		
Former	346 (12.9)	306 (12.0)	295 (12.8)		
Never	1595 (59.5)	1432 (56.2)	1264 (54.7)		
Passive smoke				0	0.9353
Yes	876 (28.6)	849 (29.0)	774 (29.0)		
No	2188 (71.4)	2084 (71.0)	1897 (71.0)		
Kitchen				71	<.0001
Yes	2933 (96.4)	2713 (93.2)	2424 (91.8)		
No	111 (3.7)	198 (6.8)	218 (8.3)		
Sleep time (/hour)				0	<.0001
<6	892 (29.1)	924 (31.5)	921 (34.5)		
6-7	720 (23.5)	619 (21.1)	482 (18.1)		
7-9	1227 (40.1)	1134 (38.7)	980 (36.7)		
>9	225 (7.3)	256 (8.7)	288 (10.8)		
Restless Days				0	0.0007
<1 Day	1522 (55.2)	1345 (51.4)	1180 (49.6)		
1-2 Days	378 (13.7)	375 (14.3)	337 (14.2)		
3-4 Days	389 (14.1)	364 (13.9)	355 (14.9)		

5-7 Days	469 (17.0)	535 (20.4)	506 (21.3)

Table 2 Associations of years of solid fuel use with sleep quality in adjusted model

	Solid fuel use for 1-4yr vs. 0		Solid fuel use for >=5yr vs. 0		Ever used solid fuel users vs. 0	
Outcomes	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Actual sleep time (/hour)						
<6	1.03 (0.90, 1.18)	0.668	1.17(1.02,1.35)*[a]	0.030	1.09 (0.96, 1.23)	0.178
6-7	0.97 (0.83, 1.12)	0.633	0.90 (0.77 1.06)	0.208	0.94 (0.82, 1.07)	0.360
7-9	Reference	/	Reference	/	Reference	/
>9	1.03 (0.83, 1.28)	0.789	1.23 (0.98, 1.54)	0.069	1.11 (0.92, 1.35)	0.281
Restless days						
<1 Day	Reference	/	Reference	/	Reference	/
1-2 Days	1.14 (0.96, 1.34)	0.135	1.19 (0.99, 1.42)	0.064	1.16 (0.99, 1.35)	0.062
3-4 Days	1.06 (0.90, 1.26)	0.484	1.28 (1.07, 1.53)*	0.006	1.15 (0.99, 1.34)	0.070
5-7 Days	1.26 (1.09, 1.47) *	0.002	1.33 (1.13, 1.56)*	0.001	1.29 (1.12, 1.48) *	0.0003

*p-value < 0.05.

Adjusted for age, gender, living area, household expenditure, education, marital status, smoking habits (active and passive) and whether the house has a separate kitchen. N=8,668.
Solid fuel use for 0yr (N=3064) was the reference for solid fuel use for 1-4 years (N=2933), >=5 years (N=2671) and participants ever used solid fuels (N=5604).

Table 3 Associations of years of solid fuel use with sleep quality stratified by age

	45-65		> 65			
Outcomes	Ever used users vs. 0	long-term users vs. 0	Ever used users vs. 0	long-term users vs. 0		
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	P[a]	P[b]
Actual sleep time (/hour)						
<6	1.09 (0.94, 1.25)	1.14 (0.96, 1.35)	1.13 (0.89 1.44)	1.31 (1.00, 1.73)	0.244	0.462
6-7	0.96 (0.82, 1.12)	0.95 (0.79, 1.15)	0.89 (0.68, 1.18)	0.81 (0.58, 1.11)	0.244	0.108
7-9	Reference	Reference	Reference	Reference		
>9	1.04 (0.82, 1.31)	1.08 (0.82, 1.43)	1.35 (0.95, 1.92)	1.63 (1.11,2.42)*	0.486	0.304
Restless days						

<1 Day	Reference	Reference	Reference	Reference		
1-2 Days	1.17	1.16	1.11	1.23	0.227	0.577
	(0.98, 1.40)	(0.93, 1.43)	(0.82, 1.50)	(0.88, 1.73)		
3-4 Days	1.17	1.35	1.12	1.17	0.638	0.368
	(0.98, 1.40)	(1.10, 1.66)*	(0.82, 1.52)	(0.83, 1.66)		
5-7 Days	1.18	1.22	1.63	1.68	0.226	0.381
	(1.01,1.39)*	(1.01, 1.48)*	(1.24, 2.13)*	(1.24, 2.27)*		

*p-value < 0.05.

Here p-value measures the statistical significance of potential modification effects. P[a] indicates the statistical difference between participants reported solid fuels use in any waves in two groups. P[b] indicates the statistical difference between long-term users (≥5 years) in two groups. Ever used users contains long-term users.

Adjusted for gender, living area, household expenditure, education, marital status, smoking habits (active and passive) and whether the house has a separate kitchen. N=8,668.

Solid fuel use for 0yr in two groups (N=2265 and 783) were the references for participants ever used solid fuels (N=3674 and 1907) and long-term users for >=5 years (N=1664 and 1000).

Table 4 Associations of years of solid fuel use with sleep quality stratified by gender

	female		male			
Outcomes	Ever used users vs. 0	long-term users vs. 0	Ever used users vs. 0	long-term users vs. 0		
	OR (95% CI)	OR (95% CI)	OR(95% CI)	OR (95% CI)	P[a]	P[b]
Actual sleep time (/hour)						
<6	1.08	1.17	1.10	1.18	0.679	0.635
	(0.91, 1.28)	(0.96, 1.43)	(0.92 1.31)	(0.96, 1.46)		
6-7	0.98	0.99	0.90	0.83	0.156	0.065
	(0.80, 1.20)	(0.78, 1.26)	(0.75, 1.08)	(0.66, 1.03)		
7-9	Reference	Reference	Reference	Reference		
>9	1.04	1.10	1.20	1.39	0.489	0.334
	(0.79, 1.36)	(0.81, 1.50)	(0.90, 1.59)	(1.01,1.91)*		
Restless days						
<1 Day	Reference	Reference	Reference	Reference		
1-2 Days	1.15	1.12	1.18	1.26	0.551	0.186
	(0.93, 1.42)	(0.86, 1.45)	(0.95,1.46)	(0.98, 0.62)		
3-4 Days	1.14	1.27	1.19	1.33	0.827	0.751
	(0.94, 1.39)	(1.01, 1.61)*	(0.93, 1.51)	(1.00,1.75)*		
5-7 Days	1.38	1.47	1.18	1.16	0.290	0.186
	(1.15, 1.66) *	(1.18, 1.82) *	(0.96, 1.46)	(0.90,1.48)		

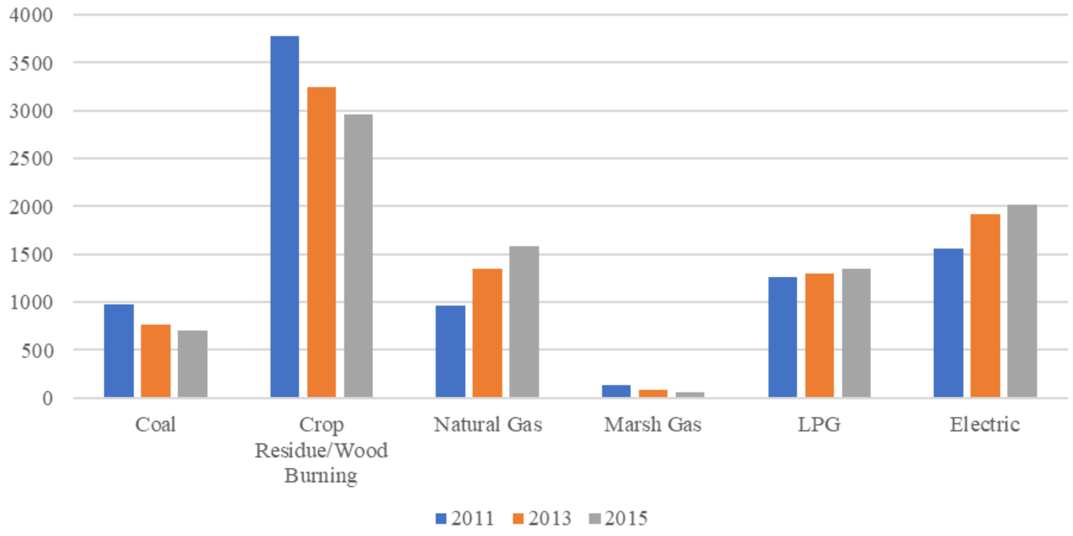
*p-value < 0.05.

Here p-value measures the statistical significance of potential modification effects. P[a] indicates the statistical difference between participants reported solid fuels use in any waves in two groups. P[b] indicates the statistical difference between long-term users (≥5 years) in two groups. Ever used users contains long-term users.

Adjusted for age, living area, household expenditure, education, marital status, smoking habits (active and passive) and whether the house has a separate kitchen. N=8,668.

Solid fuel use for 0yr in two groups (N=1560 and 1494) were the references for participants ever used solid fuels (N=2834 and 2752) and long-term users for >=5 years (N=1345 and 1315).

Figure 1 Fuel types for cooking reported in three waves



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