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The association between solid fuel use for heating and cooking and low back pain and neck pain in middle-aged to elderly Chinese adults: a cross-sectional and panel data analysis

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Abstract

Objective In low - and middle-income countries, a large number of people still use solid fuels, including crop residues such as biofuels/wood and coal, for heating and cooking. Compared with clean fuels(electric, liquefied petroleum gas, natural gas, marsh gas and solar), solid fuels can cause numerous health hazards. There is limited evidence suggesting that the use of solid fuel is associated with self-perceived low back pain (LBP) and neck pain (NP). This study aimed to analyze the association between household solid fuel use and the risk of LBP and NP in middle aged and elderly adults.

Methods We used data from the China Health and Retirement Longitudinal Study for five cross-sectional and ten panel analyses. Multivariable logistic regression model and generalized estimation equation were used to elucidate the relationship between solid fuel and the number of solid fuels used and two pains(LBP and NP). Moreover, the effect of fuel type conversion on LBP and NP is also done.

Results The results indicate that users of solid fuels, particularly those using solid cooking fuels, may have a higher risk of LBP(OR: 1.13, 95% CI: 1.05–1.22 for 2011–2020) and NP(OR: 1.22, 95% CI: 1.13–1.31 for 2018–2020). The use of solid fuels for heating also raises the risk of LBP(OR: 1.15, 95% CI: 1.06–1.24 for 2011–2020) and NP(OR: 1.34, 95% CI: 1.22–1.46 for 2015–2020). Compared to complete clean fuel users, both mixed fuel and complete solid fuel users face a greater risk for LBP (OR: 1.29, 95% CI: 1.17–1.43 for complete solid fuel users) and NP(OR: 1.38, 95% CI: 1.22–1.55 for complete solid fuel users). Additionally, persistent solid fuel users and those who switch fuel types exhibit higher risks of LBP (OR: 1.33, 95% CI: 1.20–1.47 for persistent solid fuel heating; OR: 1.39, 95% CI: 1.26–1.54 for persistent solid fuel cooking) and NP (OR: 1.38, 95% CI: 1.20–1.59 for persistent solid fuel heating; OR: 1.34, 95% CI: 1.17–1.54 for persistent solid fuel cooking) than persistent clean fuel users.

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Conclusion Long-term exposure to household solid fuels is associated with a higher risk of LBP and NP. It is suggested that multiple departments cooperate to increase the global use of clean energy and thereby reduce the risk of LBP and NP among middle-aged and elderly people.

Keywords Indoor air pollution, Household solid fuel, Low back pain, Neck pain

Introduction

Low back pain(LBP) and neck pain(NP) are two prominent global public health problems that seriously affect daily life [1–3]. In the global burden of disease (GBD) studies, LBP represents the first cause of years lived with disability (YLDs) and is a significant contributor to disability-adjusted life years (DALYs) [1]. Additionally, NP is listed as one of the top five musculoskeletal disorders affecting human health [1]. The number of people with neck pain is projected to increase by 32·5% globally to 269 million by the year 2050 [4]. Most Chinese adults will encounter disabling LBP or NP at some stage in their lives [5]. In middle-aged and elderly people, the prevalence of LBP and NP is as high as 20-40% [6]. Therefore, the prevention of LBP and NP in this age group holds even greater significance.

To the best of our knowledge, existing research has revealed several factors that affect LBP and NP, including falls, hypertension, asthma, diabetes, smoking and so on [7–10]. However, few studies have revealed the relationship between fuel usage and LBP and NP. According to previous studies, middle-aged and elderly people often use solid fuels for cooking and heating, which may increase repetitive movements among them [11]. Because solid fuels mainly refer to crop straw/wood and coal, the acquisition and usage of these fuels will increase repetitive movements [11]. Repetitive movement is a risk factor for LBP and NP [12, 13]. The reliance on solid fuels often entails a series of repetitive physical motions among the elderly population, including the collection, transportation, preparation, and management of the fuel, as well as the operation of stoves [11, 14]. These repetitive actions, performed over extended periods, can place excessive stress on the musculoskeletal system, particularly the lower back and neck [12, 13]. Middle - aged and elderly people, whose physiological functions are in a state of decline, are more vulnerable to the negative effects of repetitive stress on the spine [15].

Notably, in one health concept, environmental factors, including air pollution, played an important role in the physiological regulatory mechanisms of chronic pain [16, 17]. Currently, indoor air pollution (IAP) has emerged as a significant global environmental health issue [18–20]. According to previous research, the use of household solid fuels can contribute significantly to indoor air pollution [21]. Around 3.8 billion people worldwide are exposed to indoor air pollution(IAP) from the use of polluting fuels [22]. A study in Sweden examined the effects of living conditions including indoor air on headaches [23]. A study found that indoor air quality can affect neck pain, and poor indoor air quality may aggravate neck pain [24]. Research in India has found that during the pandemic lockdown, when indoor air quality deteriorates, people may experience low back pain [25]. A study showed that more than 700 million people in China, especially the middle-aged and elderly, continue to use solid fuels [26]. Previous studies have determined that the use of household solid fuels by middle-aged and elderly people in China increases the risks of hypertension, falls, cardiovascular diseases, lung diseases, etc [27–29]. Studies have shown that these diseases have a certain degree of impact on both LBP and NP [30, 31].

However, there is currently little evidence of a relationship between household solid fuel use and the increased prevalence of LBP and NP. It is a huge knowledge gap that needs more exploration at a time when the prevalence of LBP and NP is increasing [2, 4]. Moreover, existing studies lack not only cross-sectional evidence, but also long-term longitudinal evidence, making it difficult to infer causality.

Thus, to fill the knowledge gap, we for the first time used a large cohort data from China with multiple follow-up periods to explore the relationship between household solid fuels and LBP and NP. Therefore, we had three aims in this study. Firstly, to explore the effects of solid fuel use for cooking and heating on LBP and NP. Secondly, the study explored the relationship between the number of solid fuels used and LBP and NP. Thirdly, we further explored the effects of fuel type switching on LBP and NP over a nine-year period. Finally, our findings provide evidence to promote indoor clean energy conversion and environmental health policy development.

Method

Study population

Our research sample is from the China Health and Retirement Longitudinal Study (CHARLS). CHARLS collects data through face-to-face surveys of interviewers, including demographic information, health status information, family economic information and so on. From 2011 to 2020, CHARLS has conducted five surveys, involving 28 provinces and 150 counties in China, which is currently a microdata set with good national representation in China. Details can be found on the official website (http://charls.pku.edu.cn/). CHARLS received approval

from the Biomedical Ethics Committee of Peking University (approval number IRB00001052–11015).

This study recruited participants from wave 2011 to wave 2020 to examine the association between household fuels and LBP and NP. Firstly, we excluded individuals who were younger than 45 years of age. Participants lacking data on household fuel usage were also excluded from the study. Moreover, for the LBP and NP, participants with incomplete data for each respective outcome were subsequently excluded. Ultimately, 12,897, 13,125, 15,689,17,645 and 17,062 participants were respectively included in wave 2011, 2013, 2015, 2018 and 2020. (Figure S1) Based on the 5 wave cross-sectional data, we conducted several panel data analyses. (Figure S2) In order to enhance the reliability of our study, we referred to the Strengthening Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Solid fuel use measurements

In this study, household solid fuels were divided into two types: heating solid fuels and cooking solid fuels. In terms of heating solid fuels, "What is the primary source of heating fuel used in your home?". It is used to determine whether solid fuel is used [32]. To assessing solid fuel usage in cooking, we used the following question: " What is the main source of cooking fuel?" [32]. As with previous studies, a variable for any polluting fuel use for heating was constructed as 1) household used polluting heating fuel and 0) no polluting fuel use [33]. Similarly, we constructed cooking pollution fuel variable. A variable for any polluting fuel used for cooking was constructed as 1) household used polluting cooking fuel and 0) no polluting fuel use [33]. According to previous research, we define participants who use biofuels, including crop residues/wood and coal, as solid fuel users, while clean fuels users were regarded as electric, liquefied petroleum gas, natural gas, marsh gas and solar [34]. Studies have shown that these clean fuels produce less indoor air pollution [35].

LBP and NP measurements

The assessments of LBP and NP were derived from the health status and functioning questionnaires administered during both baseline and follow-up surveys. The assessment of two pain events was conducted using the following questions: "Are you often troubled with any part of body pains?" and "What part of your body do you feel pain?". Participants were defined as having LBP and NP if they answered NP and LBP [5].

Covariates

According to previous literature, potential covariates were adjusted in models, including sex (female or male), age(<60 or ≥60), residence(urban or rural), marital status (divorced/separated, married/cohabitation), education (illiterate, primary school or below, middle school, high school or above), smoking status(no or yes), drinking status(no or yes), fall(no or yes), self-rated health(good, general or poor) and number of chronic diseases (0, 1, 2 or ≥3) [36, 37]. Chronic diseases, such as diabetes, hypertension, dyslipidemia, chronic lung disease, cardiovascular disease, kidney disease, stroke, gastrointestinal disorders, arthritis or rheumatism, and asthma were identified based on self-reported physician diagnoses [26].

Statistical analyses

For the baseline characteristics, we treated all variables as categorical variables and then presented them in frequency (percentages). We used Chi-square tests in our baseline analysis to examine potential differences in fuel usage among various groups. Meanwhile, we used five waves' data to show trends in the prevalence of LBP and NP over 9 years.

We performed a diverse statistical analysis of LBP and NP based on the type of household fuels. Firstly, to explore the associations between household solid fuels used for heating and cooking and two chronic pains (LBP and NP), Multivariate logistic regression was used in cross-sectional analyses. We further investigated the associations between the exclusive and combined use of household solid fuels for cooking and heating, and the risk of LBP and NP. Participants were categorized into three groups: complete solid fuel users, mixed fuel users (solid fuel for heating and clean fuel for cooking, or clean fuel for heating and solid fuel for cooking), and complete clean fuel users. Moreover, to examine the lag effects after a period of use, panel data were analyzed by Generalized estimating equations (GEE) to calculate odds ratios (ORs) and 95% confidence intervals (CIs) according to interval of survey (including 2011 to 2013, 2011 to 2015, 2011 to 2018, 2011 to 2020, 2013 to 2015, 2013 to 2018, 2013 to 2020, 2015 to 2018, 2015 to 2020, 2018 to 2020). In addition, we examined the relationships between the conversion of fuel types used for heating and cooking and their associations with LBP and NP. We used an analysis of the conversion of fuel types utilizing panel data spanning from 2011 to 2020. We categorize fuel conversion into four distinct types: clean-to-solid fuel conversion, solid-to-clean fuel conversion, persistent users of clean fuels, and persistent users of solid fuels. For each analysis, three distinct models were employed to separately assess the correlations. We did not make any adjustment to the crude model. Then, model 1 was adjusted for age and sex. Model 2 was fully adjusted for educational levels, marriage status, residential area, smoking, drinking, fall, the number of chronic diseases, and self-rated health based on model 1.

Next, we conducted subgroup analysis and interactive analysis. We interacted with each control variable with two solid fuel use variables. At the same time, we divided subgroups according to sex, education, marital status, residential area, smoking, drinking, fall, the number of chronic diseases, and self-rated health. Finally, the stability of the model was verified through three kinds of sensitivity analyses. First, we replaced the variable of the number of chronic diseases and added different chronic disease into the model three times for control. According to previous studies, these chronic diseases are all related to LBP and NP and can also be affected by solid fuel use [35]. Secondly, we excluded the samples that had LBP and NP at the 2011 baseline and examined the samples that did not have LBP and NP at the baseline from 2011 to 2013, 2011 to 2015, 2011 to 2018, and 2011 to 2020. Thirdly, we adjusted the p-value based on Bonferroni-correction, and adjusted the confidence interval to 99%, and then reviewed the baseline samples in 2011 and the samples from 2011 to 2013.The statistical analysis was performed using Stata 17.0, with a P value of less than 0.05 considered statistically significant for a two-tailed test.

Results

Baseline participant characteristics

The baseline characteristics for 2011 are shown below. A total of 12,897 people participated in the baseline survey, with female accounting for 52.26%. We found that the use of clean fuels was higher among middle-aged people(59.21% vs. 53.58% for heating; 59.53% vs. 52.21% for cooking), but the use of solid fuels was higher among older people(46.42% vs. 40.79% for heating; 47.79% vs. 40.47% for cooking). In addition, we found that people who were divorced or separated (13.36% vs. 11.48% for heating; 13.25% vs. 12.05% for cooking), with lower levels of education(53.72% vs. 31.9% illiterate for heating; 56.26% vs. 33.99% illiterate for cooking), living in rural areas(74.15% vs. 30.9% for heating; 78.21% vs. 36.21% for cooking), with a history of smoking (41.42% vs. 36.50% for heating; 41.48% vs. 37.59% for cooking), higher numbers of chronic diseases(19.65% vs. 18.22% for heating; 19.65% vs. 18.56% for cooking), with a history of falls(16.65% vs. 13.73% for heating; 17.74% vs. 13.11% for cooking) and Self-rated poor health (32.81% vs. 19.40% for heating; 34.17% vs. 20.93% for cooking) reported more solid fuel use. (Table 1)

Association between the use of solid fuel with LBP and NP using cross-sectional data

For each wave of data, we assessed the prevalence of LBP and NP in the heating clean fuels user group, the cooking clean fuels user group, the heating solid fuels user group, and the cooking solid fuels user group. The analysis revealed that the prevalence of LBP in the full sample increased from 19.87% in 2011 to 33.36% in 2020. Similarly, the prevalence of NP in the full sample rose from 7.27% in 2011 to 15.31% in 2020. We found that the prevalence of LBP and NP increased in all groups from 2011 to 2020 and was higher in the group that used solid fuels for heating and cooking. (Fig. 1 and Table S1 in Supplementary file)

The fully adjusted odds ratios and 95% Cis for LBP and NP are presented in relation to the use of solid heating and cooking fuels.(Fig. 2) For LBP, the use of solid fuels for heating(ORs and 95% CIs in 2011, 2013, 2015, 2018, 2020 wave separately: 1.64, 95% CI: 1.46–1.85; 1.23, 95% CI: 1.10–1.38; 0.86, 95% CI: 0.72–1.03; 1.06, 95% CI: 0.91–1.23; 1.20, 95% CI: 1.11–1.29) and cooking(ORs and 95% CIs in 2011, 2013, 2015, 2018, 2020 wave separately: 1.51, 95% CI: 1.35–1.68; 1.31, 95% CI: 1.21–1.49; 1.30, 95% CI: 1.19–1.42; 1.27, 95% CI: 1.18–1.37; 1.18, 95% CI: 1.09–1.28) has a significant impact. This trend was particularly pronounced among users of solid cooking fuels. Compared to individuals who utilized cleaner fuels, those who relied on solid fuels exhibited a higher risk of developing NP.(ORs and 95% CIs in 2011, 2013, 2015, 2018 2020 wave for heating separately: 1.38, 95% CI: 1.16–1.65; 1.49, 95% CI: 1.23–1.82; 1.25, 95% CI: 1.03–1.57; 1.29, 95% CI: 1.08–1.54; 1.22, 95% CI 1.11–1.34. ORs and 95% CIs in 2011, 2013, 2015, 2018 2020 wave for cooking separately: 1.28, 95% CI: 1.09–1.51; 1.33, 95% CI: 1.11–1.60; 1.25, 95% CI: 1.11–1.40; 1.23, 95% CI: 1.12–1.34; 1.23, 95% CI 1.11–1.36) More detailed model results are presented here. (Table S2 and S3 in Supplementary file)

At the same time, we examined the relationship between fuel quantity and LBP and NP. We found a significant positive association between fuel quantity and LBP. We observed that the risk of LBP for users of complete solid fuels was 88%(OR: 1.88, 95% CI: 1.64–2.16), 39%(OR: 1.39, 95% CI: 1.22–1.59), 35%(OR: 1.35, 95% CI: 1.04–1.74), and 29%(OR: 1.29, 95% CI: 1.17–1.43) higher compared to users of complete clean fuels in the years 2011, 2013, 2018, and 2020, respectively. Besides, We found that in the years 2011, 2015, 2018, and 2020, users of mixed fuels exhibited a significantly higher risk of LBP compared to users of complete clean fuels, with increases of 40%(OR: 1.40, 95% CI: 1.20–1.63), 27%(OR: 1.27, 95% CI: 1.16–1.38), 24%(OR: 1.24, 95% CI: 1.15–1.33), and 15%(OR: 1.15, 95% CI: 1.06–1.25) respectively. (Table 2) For NP, we observed that mixed fuels users for cooking and heating in 2011, 2015, and 2018 had a 27%(OR: 1.27, 95% CI: 1.01–1.59), 28%(OR: 1.28, 95% CI: 1.14–1.44), and 22%(OR: 1.22, 95% CI: 1.12–1.33) higher risk of developing NP than complete clean fuels users. Moreover, We observed that the risk of NP for users of complete solid fuels was 50%(OR: 1.50, 95% CI: 1.22–1.84), 63%(OR: 1.63, 95% CI: 1.29–2.06), 60%(OR: 1.60, 95% CI:

Table 1 Baseline characteristics of participants according to type of heating and cooking fuel

Characteristics	Heating			Cooking		
	Clean fuels(%)	Solid fuels(%)	*P*	Clean fuels(%)	Solid fuels(%)	*P*
Age			< 0.001			< 0.001
< 60	2652(59.21)	4510(53.58)		3487(59.53)	3675(52.21)	
≥ 60	1827(40.79)	3908(46.42)		2371(40.47)	3364(47.79)	
Gender			0.547			0.989
Female	2357(52.62)	4383(52.07)		3061(52.25)	3679(52.27)	
Male	2122(47.38)	4035(47.93)		2797(47.75)	3360(47.73)	
Marital status			0.002			0.041
Divorced/separated	514(11.48)	1125(13.36)		706(12.05)	933(13.25)	
Married/cohabitation	3965(88.52)	7293(86.64)		5152(87.95)	6106(86.75)	
Education			< 0.001			< 0.001
Illiterate	1429(31.9)	4522(53.72)		1991(33.99)	3960(56.26)	
Primary school or below	840(18.75)	1848(21.95)		1152(19.67)	1536(21.82)	
Middle school	1160(25.9)	1437(17.07)		1468(25.06)	1129(16.04)	
High school or above	1050(23.44)	611(7.26)		1247(21.29)	414(5.88)	
Residential area			< 0.001			< 0.001
Urban	3095(69.1)	2176(25.85)		3737(63.79)	1534(21.79)	
Rural	1384(30.9)	6242(74.15)		2121(36.21)	5505(78.21)	
Drinking			0.918			0.86
No	2727(60.88)	5133(60.98)		3575(61.03)	4285(60.88)	
yes	1752(39.12)	3285(39.02)		2283(38.97)	2754(39.12)	
Smoking			< 0.001			< 0.001
No	2844(63.5)	4931(58.58)		3656(62.41)	4119(58.52)	
yes	1635(36.5)	3487(41.42)		2202(37.59)	2920(41.48)	
Number of chronic diseases			0.069			0.011
0	1439(32.13)	2551(30.3)		1892(32.30)	2098(29.81)	
1	1337(29.85)	2486(29.53)		1733(29.58)	2090(29.69)	
2	887(19.8)	1727(20.52)		1146(19.56)	1468(20.86)	
≥ 3	816(18.22)	1654(19.65)		1087(18.56)	1383(19.65)	
Fall			< 0.001			< 0.001
No	3864(86.27)	7016(83.35)		5090(86.89)	5790(82.26)	
yes	615(13.73)	1402(16.65)		768(13.11)	1249(17.74)	
Self-rated health			< 0.001			< 0.001
Good	1281(28.6)	1695(20.14)		1659(28.32)	1317(18.71)	
General	2329(52)	3961(47.05)		2973(50.75)	3317(47.12)	
Poor	869(19.4)	2762(32.81)		1226(20.93)	2405(34.17)	

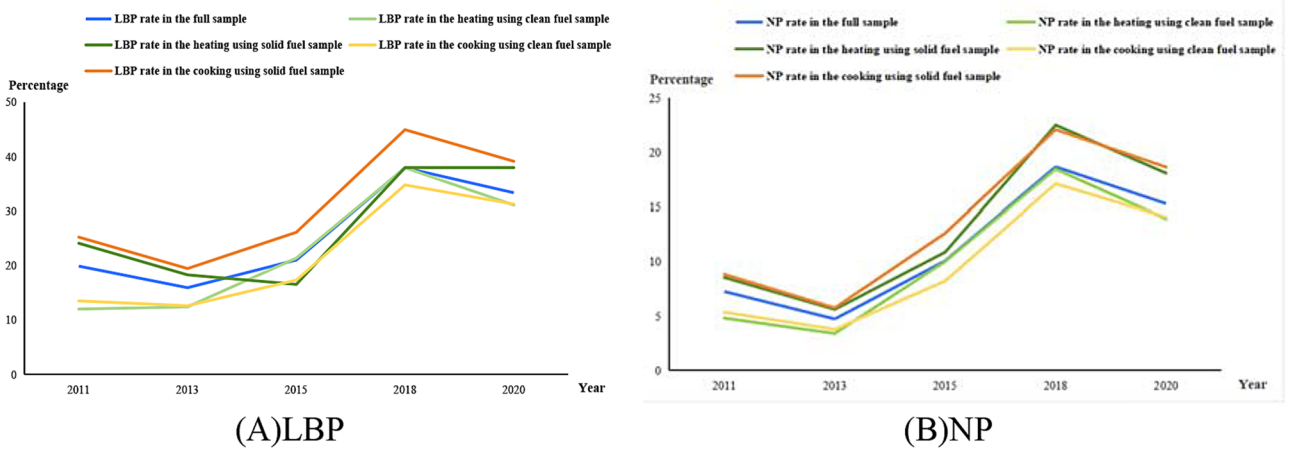

Fig. 1 Prevalence of LBP and NP in different populations. Note: LBP stands for low back pain; NP stands for neck pain

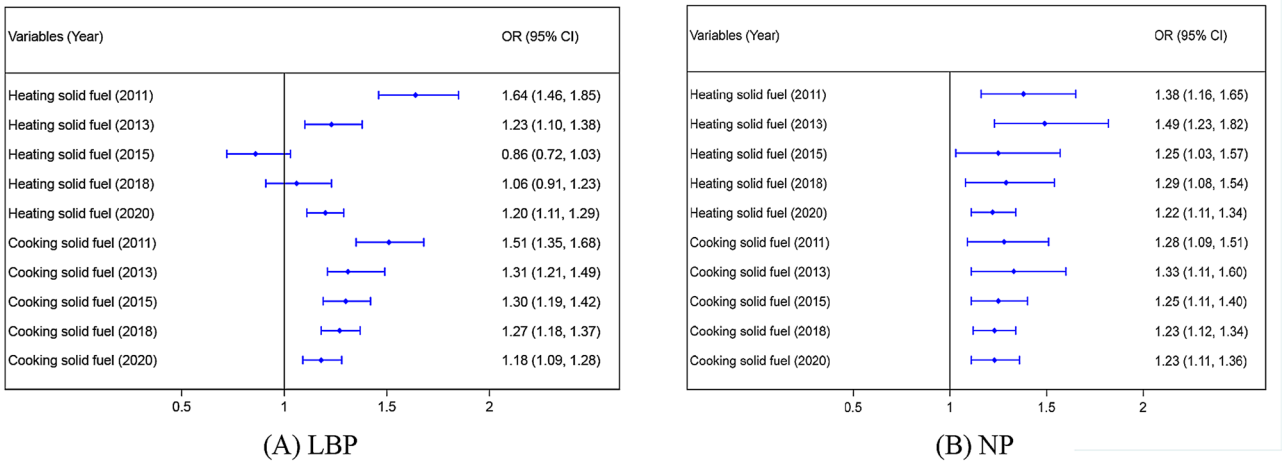

Fig. 2 Adjusted odds ratios and 95% confidence intervals of NP and LBP in relation to using solid fuel for heating and cooking. Note: LBP stands for low back pain; NP stands for neck pain. The sample size was 12,897 in 2011, 13,125 in 2013, 15,689 in 2015, 17,645 in 2018, and 17,062 in 2020

Table 2 Single and combined use of solid fuel for heating and cooking and low back pain

Year	Model	Complete clean fuels for heating and cooking	Mixed use of clean fuels and solid fuels for heating and cooking	*p*	Complete solid fuels for heating and cooking	*p*
2011	Crude	1.00 (Ref)	1.73(1.50–1.99)	< 0.001	2.86(2.55–3.22)	< 0.001
	Model 1	1.00 (Ref)	1.74(1.51–2.01)	< 0.001	2.88(2.56–3.23)	< 0.001
	Model 2	1.00 (Ref)	1.40(1.20–1.63)	< 0.001	1.88(1.64–2.16)	< 0.001
2013	Crude	1.00 (Ref)	1.38(1.21–1.57)	< 0.001	1.92(1.71–2.15)	< 0.001
	Model 1	1.00 (Ref)	1.38(1.21–1.57)	< 0.001	1.91(1.70–2.14)	< 0.001
	Model 2	1.00 (Ref)	1.09(0.95–1.26)	0.217	1.39(1.22–1.59)	< 0.001
2015	Crude	1.00 (Ref)	1.56(1.45–1.69)	< 0.001	1.25(0.92–1.69)	0.149
	Model 1	1.00 (Ref)	1.55(1.43–1.68)	< 0.001	1.25(0.93–1.71)	0.142
	Model 2	1.00 (Ref)	1.27(1.16–1.38)	< 0.001	0.95(0.68–1.32)	0.759
2018	Crude	1.00 (Ref)	1.46(1.37–1.55)	< 0.001	1.58(1.25-2.00)	< 0.001
	Model 1	1.00 (Ref)	1.46(1.37–1.56)	< 0.001	1.60(1.26–2.03)	< 0.001
	Model 2	1.00 (Ref)	1.24(1.15–1.33)	< 0.001	1.35(1.04–1.74)	0.023
2020	Crude	1.00 (Ref)	1.30(1.21–1.40)	< 0.001	1.57(1.44–1.71)	< 0.001
	Model 1	1.00 (Ref)	1.30(1.20–1.40)	< 0.001	1.56(1.43–1.71)	< 0.001
	Model 2	1.00 (Ref)	1.15(1.06–1.25)	0.001	1.29(1.17–1.43)	< 0.001

Note: Crude: unadjusted; Model 1: adjusted for age and sex; Model 2: adjusted for smoking, drinking, education, marital status, residence, number of chronic diseases, self-rated health, fall upon Model 1; Ref: reference

1.20–2.14), and 38%(OR: 1.38, 95% CI: 1.22–1.55) higher compared to users of complete clean fuels in the years 2011, 2013, 2018, and 2020, respectively. (Table 2 and Table S4 in Supplementary file)

Association between the use of solid fuel with LBP and NP using panel data

Panel data were analyzed to provide further evidence between the use of solid fuel and LBP and NP. We used five waves of survey data to generate ten panel data sets for analysis. Firstly, we studied the association between solid fuels use and LBP. We found that across 8 panel data sets, using solid fuel for cooking was consistently positively managed with LBP, increasing LBP risk. For instance, we observed that cooking with solid fuels increased the risk of LBP by 50%(OR: 1.50, 95% CI: 1.37–1.64), 48%(OR: 1.48, 95% CI: 1.36–1.60), 13%(OR: 1.13, 95% CI: 1.05–1.22) and 23%(OR: 1.23, 95% CI: 1.13–1.30), respectively, between 2011 and 2013, 2011 to 2015, 2011 to 2020 and 2018 to 2020. Meanwhile, we also found that the use of solid fuels for heating is dangerous for LBP. For example, solid heating fuel use was found to be associated with increased risk of LBP in the period 2011 to 2013(OR: 1.40, 95% CI: 1.27–1.55), 2011 to 2015(OR: 1.33, 95% CI: 1.23–1.44), 2011 to 2020(OR: 1.15, 95% CI: 1.06–1.24) and 2015 to 2020(OR: 1.36, 95% CI: 1.26–1.46). But we observed that the use of solid fuels for heating reduces the risk of LBP in our analysis of four panel datasets. The four panel datasets all cover 2015 or 2018, which, like previous studies, may be due to limitations in

the collection of solid fuel heating data in 2015 and 2018. (Fig. 3 and Table S5 in Supplementary file).

Regarding NP, we found that the use of solid cooking fuels increases its risk. Solid cooking fuel use was found to be associated with increased risk of NP in the period 2011 to 2013(OR: 1.34, 95% CI: 1.17–1.55), 2011 to 2015(OR: 1.21, 95% CI: 1.08–1.36), 2013 to 2015(OR: 1.28, 95% CI: 1.15–1.44), 2015 to 2018(OR: 1.13, 95% CI: 1.04–1.22), 2015 to 2020(OR: 1.16, 95% CI: 1.06–1.26) and 2018 to 2020(OR: 1.22, 95% CI: 1.13–1.31). Moreover, we found that solid fuel use for heating increased NP risk between 2011 and 2013(OR: 1.47, 95% CI: 1.26–1.73) and between 2015 and 2020(OR: 1.34, 95% CI: 1.22–1.46). In most periods, there was no evidence of statistical correlation between heating solid fuel users and NP. Meanwhile, we observed three datasets covering either 2015 or 2018 that showed that using solid fuels for heating reduced NP risk. As with previous studies, this may be due to a certain amount of missing data on solid fuel collection for heating in 2015 and 2018. (Fig. 3 and Table S6 in Supplementary file)

We analyzed the impact of fuel type switching on LBP and NP using 2011 and 2020 data, combined as panel datasets. We identify four distinct types of fuel conversion that occurred between 2011 and 2020: consistent use of clean fuels, transition from solid fuels to clean fuels, shift from clean fuels to solid fuels, and persistent reliance on solid fuels.(Fig. 4) For LBP, the persistent use on solid fuels for heating(OR: 1.33, 95% CI: 1.20–1.47) or cooking(OR: 1.39, 95% CI: 1.26–1.54) aggravated the risk in comparison to the persistent use of clean fuels. Users who switch from solid fuels to cleaner fuels still have a higher LBP risk(OR: 1.20, 95% CI: 1.08–1.33 for heating; OR: 1.29, 95% CI: 1.17–1.42 for cooking) than those who continue to use cleaner fuels. For NP, we found that groups that consistently use solid fuels have a higher NP risk(OR: 1.38, 95% CI: 1.20–1.59 for heating; OR: 1.34, 95% CI: 1.17–1.54 for cooking) than groups that consistently use clean fuels. Meanwhile, users who switch from solid fuels to cleaner fuels still have a higher NP risk(OR: 1.18, 95% CI: 1.02–1.37 for heating; OR: 1.17, 95% CI: 1.02–1.33 for cooking) than those who continue to use cleaner fuels.(Table 3).

Subgroup analysis and sensitivity analysis

In all subgroups, we found that the use of solid fuels for heating and cooking exacerbated the risk of LBP. Interaction analysis revealed an interaction between self-rated health and solid fuel use for heating and cooking(p for interaction < 0.05). (Table 4) For NP, we observed age(p for interaction < 0.05) and drinking(p for interaction < 0.05) have an interaction effect. Further, increased risk of NP was found in solid fuel users who were older, had a history of drinking.(Table S7 in Supplementary file) Finally, we conducted a sensitivity analysis. We replaced the variable of chronic disease quantity with the presence or absence of specific chronic diseases to control, and we conducted an analysis by gradually adding the types

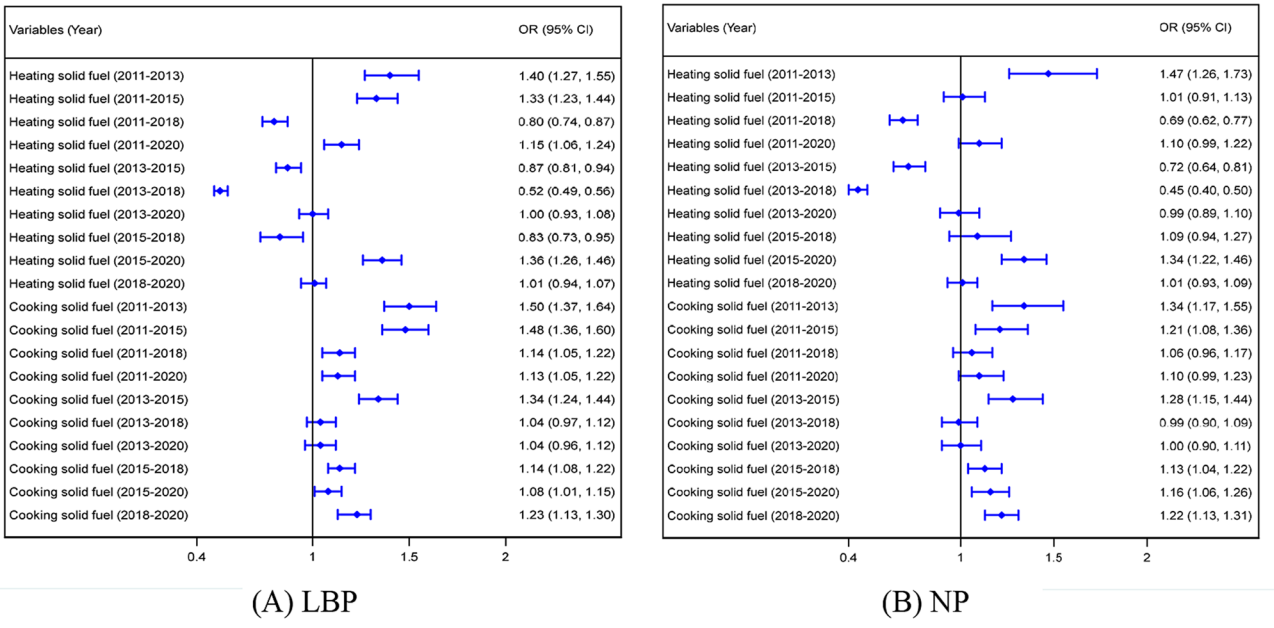

Fig. 3 Adjusted odds ratios and 95% confidence intervals of NP and LBP in relation to using solid fuel for heating and cooking. Note: LBP stands for low back pain; NP stands for neck pain. The sample size of 2011–2013 is 9,060, 2011–2015 is 9,913, 2011–2018 is 9,269, 2011–2020 is 8,676, 2013–2015 is 1,1067, 2013–2018 is 10,292, The sample size for 2013–2020 is 9,623, the sample size for 2015–2018 is 12,981, and the sample size for 2015–2020 is 12,204, the sample size for 2018–2020 is 14,854

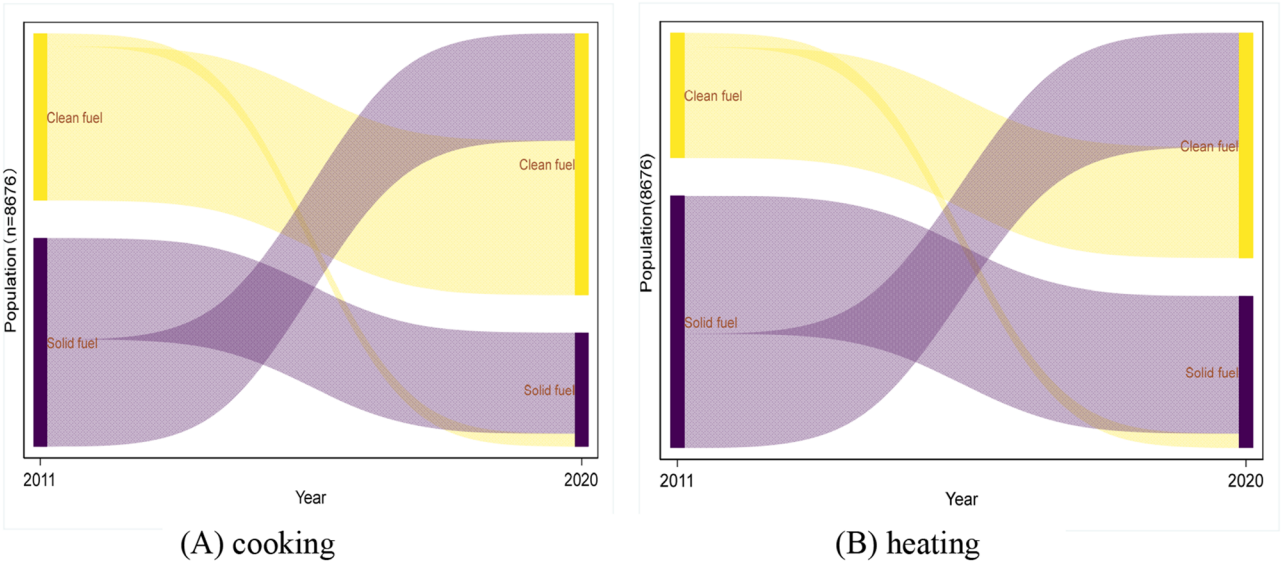

Fig. 4 Cooking and Heating fuel transitions from baseline to present. Note: Among cooking fuels, there were 3,562 continuous use of clean fuels, 300 switching from clean to solid fuels, 2479 switching from solid to clean fuels, and 2,335 continuous use of solid fuels. Among heating fuels, there were 2550 continuous use of clean fuels, 330 switching from clean to solid fuels, 2,631 switching from solid to clean fuels, and 3,165 continuous use of solid fuels

Table 3 Heating and cooking fuel types conversion for neck pain and low back pain

Variable	Fuel use	Model	Persistent clean	Solid to clean	Clean to solid	Persistent solid
NP	heating	Crude	1.00 (Ref)	1.37(1.20–1.56)	1.21(0.92–1.59)	1.73(1.53–1.95)
		Model 1	1.00 (Ref)	1.36(1.19–1.55)	1.23(0.94–1.62)	1.72(1.52–1.95)
		Model 2	1.00 (Ref)	1.18(1.02–1.37)	1.01(0.76–1.35)	1.38(1.20–1.59)
	cooking	Crude	1.00 (Ref)	1.38(1.23–1.56)	1.43(1.10–1.85)	1.71(1.52–1.92)
		Model 1	1.00 (Ref)	1.35(1.20–1.52)	1.09(1.07–1.80)	1.68(1.49–1.89)
		Model 2	1.00 (Ref)	1.17(1.02–1.33)	1.26(0.95–1.65)	1.34(1.17–1.54)
LBP	heating	Crude	1.00 (Ref)	1.45(1.32–1.58)	1.32(1.10–1.59)	1.73(1.59–1.88)
		Model 1	1.00 (Ref)	1.43(1.31–1.57)	1.35(1.12–1.63)	1.72(1.58–1.88)
		Model 2	1.00 (Ref)	1.20(1.08–1.33)	1.10(0.90–1.35)	1.33(1.20–1.47)
	cooking	Crude	1.00 (Ref)	1.54(1.42–1.67)	1.45(1.21–1.75)	1.83(1.69–1.99)
		Model 1	1.00 (Ref)	1.51(1.39–1.64)	1.41(1.17–1.70)	1.79(1.65–1.95)
		Model 2	1.00 (Ref)	1.29(1.17–1.42)	1.22(0.99–1.49)	1.39(1.26–1.54)

Note: LBP stands for low back pain; NP stands for neck pain. Crude: unadjusted; Model 1: adjusted for age and sex; Model 2: adjusted for smoking, drinking, education, marital status, residence, number of chronic diseases, self-rated health, fall upon Model 1; Ref: reference

of chronic diseases controlled. Secondly, we excluded the baseline disease samples from 2011 for the primary analysis. Thirdly, we adjusted the P value and confidence interval for the sensitivity test. The findings from the sensitivity analysis were found to be aligned with the primary results we had previously obtained.(Table S8, S9 and S10 in Supplementary file).

Discussion

This nationwide study, for the first time, identifies an intriguing association between the use of solid fuel and both LBP and NP, using a prospective design. The results suggest that users of solid fuels, especially those utilizing solid cooking fuels, may face a higher risk of LBP and NP. The use of solid fuel for heating also increases the risks of LBP and NP, but this relationship should be interpreted with caution in the context of this study and further exploration and determination are still required. Compared with complete clean fuels users, mixed fuels users and complete solid fuels users had a higher risk for LBP and NP. In addition, persistent solid fuel users, and users with fuel type switching have higher LBP and NP risks than users with persistent clean fuels.

To our knowledge, there was a few research to analyze association between solid fuels and pain, especially for LBP and NP. Previous studies found solid fuels affected body pain, it was like our finding [6]. Research has found that the use of solid fuels may increase the risk of LBP and NP in middle-aged and elderly people by increasing repetitive exercise behaviors [11, 15]. From a physiological perspective, repetitive movements (such as bending over to fetch firewood, transporting fuel, and maintaining

Table 4 Adjusted odds ratios and 95% confidence intervals of low back pain in association with using solid fuel for heating and cooking according to subgroups

Subgroup	Heating				Cooking			
	Clean fuels	Solid fuels	*p*	*p* for interaction	Clean fuels	Solid fuels	*p*	*p* for interaction
Age				0.279				0.560
< 60	1.00 (Ref)	1.63(1.39–1.90)	< 0.001		1.00 (Ref)	1.55(1.34–1.79)	< 0.001	
≥ 60	1.00 (Ref)	1.61(1.34–1.94)	< 0.001		1.00 (Ref)	1.42(1.20–1.68)	< 0.001	
Gender				0.363				0.162
Female	1.00 (Ref)	1.64(1.41–1.92)	< 0.001		1.00 (Ref)	1.47(1.28–1.69)	< 0.001	
Male	1.00 (Ref)	1.66(1.37–2.01)	< 0.001		1.00 (Ref)	1.58(1.33–1.87)	< 0.001	
Marital status				0.696				0.933
Divorced/separated	1.00 (Ref)	1.52(1.09–2.11)	0.013		1.00 (Ref)	1.48(1.11–1.98)	0.008	
Married/cohabitation	1.00 (Ref)	1.66(1.46–1.89)	< 0.001		1.00 (Ref)	1.51(1.35–1.70)	< 0.001	
Education				0.159				0.051
Illiterate	1.00 (Ref)	1.61(1.36–1.91)	< 0.001		1.00 (Ref)	1.37(1.18–1.59)	< 0.001	
Primary school or below	1.00 (Ref)	1.37(1.06–1.76)	0.016		1.00 (Ref)	1.61(1.27–2.04)	< 0.001	
Middle school	1.00 (Ref)	1.88(1.45–2.46)	< 0.001		1.00 (Ref)	1.74(1.36–2.25)	< 0.001	
High school or above	1.00 (Ref)	1.70(1.13–2.55)	0.011		1.00 (Ref)	1.54(1.00-2.36)	0.048	
Residential area				0.912				0.617
Urban	1.00 (Ref)	1.59(1.34–1.89)	< 0.001		1.00 (Ref)	1.51(1.27–1.80)	< 0.001	
Rural	1.00 (Ref)	1.65(1.40–1.95)	< 0.001		1.00 (Ref)	1.47(1.28–1.69)	< 0.001	
Drinking				0.065				0.320
No	1.00 (Ref)	1.59(1.38–1.85)	< 0.001		1.00 (Ref)	1.53(1.34–1.76)	< 0.001	
yes	1.00 (Ref)	1.74(1.42–2.13)	< 0.001		1.00 (Ref)	1.46(1.22–1.75)	< 0.001	
Smoking				0.626				0.466
No	1.00 (Ref)	1.77(1.53–2.05)	< 0.001		1.00 (Ref)	1.64(1.43–1.87)	< 0.001	
yes	1.00 (Ref)	1.43(1.17–1.76)	0.001		1.00 (Ref)	1.31(1.09–1.57)	0.004	
Number of chronic diseases				0.319				0.260
0	1.00 (Ref)	1.39(1.06–1.83)	0.019		1.00 (Ref)	1.21(0.94–1.55)	0.141	
1	1.00 (Ref)	1.86(1.48–2.34)	< 0.001		1.00 (Ref)	1.74(1.41–2.14)	< 0.001	
2	1.00 (Ref)	1.64(1.29–2.08)	< 0.001		1.00 (Ref)	1.53(1.24–1.90)	< 0.001	
≥ 3	1.00 (Ref)	1.64(1.32–2.03)	< 0.001		1.00 (Ref)	1.48(1.20–1.81)	< 0.001	
Fall				0.702				0.258
No	1.00 (Ref)	1.67(1.47–1.91)	< 0.001		1.00 (Ref)	1.57(1.39–1.78)	< 0.001	
yes	1.00 (Ref)	1.51(1.16–1.96)	0.002		1.00 (Ref)	1.27(1.00-1.61)	0.05	
Self-rated health				0.001				0.035
Good	1.00 (Ref)	2.73(1.78–4.17)	< 0.001		1.00 (Ref)	2.11(1.45–3.06)	< 0.001	
General	1.00 (Ref)	1.76(1.48–2.09)	< 0.001		1.00 (Ref)	1.51(1.29–1.77)	< 0.001	
Poor	1.00 (Ref)	1.37(1.14–1.63)	0.001		1.00 (Ref)	1.40(1.19–1.65)	< 0.001	

a fixed posture for a long time while cooking) can lead to chronic strain of muscles, tendons and joints, manifested as minor tears in local tissues, inflammatory responses and fibrosis, which is consistent with previous studies on musculoskeletal diseases [38]. For middle-aged and elderly people, the acquisition and use of solid fuel are often accompanied by high-frequency and repetitive physical movements. For instance, in rural areas, residents frequently bend over to fetch firewood from fuel piles, stand for long periods or bend over to operate stoves [11]. These movement patterns exhibit a strong alignment with the fundamental risk factors associated with LBP and NP, specifically characterized by repetitive bending loads and static posture maintenance [12, 13]. Previous studies have found that the association between solid fuel use and repetitive exercise shows significant age dependence [39]. With the increase of age, physiological changes such as the decline of muscle elasticity, the loss of water in intervertebral discs and the degeneration of articular cartilage lead to a decrease in the mechanical stress tolerance of the lumbar and neck tissues caused by repetitive movements [40]. Therefore, using solid fuel for cooking or heating increases repetitive exercise among middle-aged and elderly people. Moreover, as they age, the repetitive exercise caused by the use of solid fuel poses more risks to the waist and neck of the elderly.

On the other hand, indoor air pollution caused by the use of solid fuels may also increase the risks of LBP and NP. A study in England showed that carbon monoxide exposure can cause headaches and chest pain,

which may also indirectly cause traction pain in the neck and waist [41]. A Chinese study found that pain is a mediator between solid fuel use and the onset of disability symptoms [6]. Our findings were like this study and went further, refining for the first time the relationship between LBP and NP, two very important body pain conditions, and solid fuels in a long-term study. Meantime, this is similar with the findings of a randomized intervention trial in Mexico, where the use of improved stoves improved indoor air quality and reduced the risk of coughing, headaches and back pain [14]. Despite this research did not directly mentioning LBP and NP, back pain was the important joint between NP and LBP [7]. In addition, a large number of literatures have verified the relationship between solid fuel use and noncommunicable disease, including hypertension, diabetes, arthritis and so on [42–45]. One possible explanation is the effect of solid fuel use on these diseases, which may further exacerbate LBP and NP [6, 43, 46]. Moreover, while our findings indicate that the use of solid fuels for household purposes (cooking and heating) is associated with an elevated risk of LBP and NP, the evidence suggesting that cooking with solid fuels may contribute to a heightened risk of LBP and NP is more robust than that related to the use of solid fuels for heating. Our study was also the first to examine the effects of solid fuel use for heating and cooking on LBP and NP, respectively. This difference may be because solid fuel was used for heating and solid fuel used for cooking belongs to different patterns [47]. Cooking constitutes a vital aspect of daily life, resulting in continuous exposure over an individual's lifetime. Therefore, compared with heating, cooking with solid fuel leads to more repetitive movements and more exposures to indoor air pollution, which has a greater adverse impact on human health [48, 49].

In subgroup analysis and interaction analysis, we found that for LBP, solid fuel use un differed significantly across subgroups. In all subgroups, solid fuel use significantly increased LBP risk. This means that solid fuel use is quite harmful to LBP. It is worth noting the interaction between self-rated health and heating and cooking fuels. While subgroup analysis showed no heterogeneity, attention should still be given to the effects of solid fuel use among different self-rated health populations. Those with poor self-rated health may already be vulnerable, making them more susceptible to harm from solid fuel usage [50]. For NP, we observed that heating solid fuel use was at greater risk for older adults over 60 years of age. This is similar to a multinational study that found that solid fuels are more harmful in the elderly population [51]. This is consistent with a Chinese study, solid fuel affects the quality of sleep in the elderly, thus causing pain and other obstacles to healthy aging [52]. This may be because older people have a greater need for heating and are more likely to use solid fuels than middle-aged people [53]. Meanwhile, there is an interaction between drinking alcohol and solid fuel used for heating. But in the subgroup analysis, there was no difference. A Chinese study has shown that drinking alcohol may lead to multiple chronic diseases in the body, which in turn affect physical pain [54]. We still need to be aware of possible synergies between drinking alcohol and solid fuel use [55].

The precise molecular mechanisms by which indoor air pollution adversely impact LBP and NP remain unclear. Existing literature showed indoor air pollutants such as formaldehyde, benzene and other volatile organic compounds (VOCs) can enter the body through breathing [21]. These chemicals can trigger an inflammatory response in the body. When these harmful substances enter the blood system, they may stimulate the body's immune system, leading to a systemic inflammatory state [56]. This chronic inflammatory state can affect muscles and joints, especially those that are under constant stress, such as the LBP and NP [57]. Studies have shown that solid fuel combustion can produce a variety of aldehydes, including formaldehyde, acetaldehyde, acrolein and so on [58–60]. One study showed that certain aldehydes can aggravate neuropathic pain [61]. At the same time, acetaldehyde has been shown to cause pain in rodents [62]. Experimental studies have shown that aldehydes induce pain by activating transient receptor potential ankyrin 1 (TRPA1) [63]. These may be the mechanism paths that cause the harm of solid fuel use to LBP and NP. Despite the above biological explanations, current population studies and experimental studies are insufficient to support mechanism analysis, and more biological exploration combined with large-scale population cohort validation is needed in the future.

Under the concept of one health, there are many research efforts to solve the problem of solid fuels, thereby protecting human health [18, 28]. Several studies at domestic and abroad have shown that the energy sector's promotion of the use of clean energy helps reduce cardiovascular disease, depression and so on [64, 65]. Research also shows that improving stoves can help use clean energy, reduce repetitive movements, improve cooking postures, and reduce indoor air pollution, thereby protecting health [66, 67]. In the context of increasing ageing, these interventions have important public health implications in low- and middle-income countries around the world [46, 68]. We need to promote cross-sectoral cooperation between the energy, environment and health sectors to reduce further health losses from solid fuels.

Our research has several strengths. First, we explored the relationship between solid fuel use and LBP and NP using nationally representative data for the first time. Second, we used nine years of data, multiple analyses in

cross-sectional and panel data, and diversified statistical analysis strategies to provide long-term evidence for the effects of solid fuel use on LBP and NP. Third, we divided solid fuel use into heating and cooking, and thus explored the impact of the quantity of fuel used on LBP and NP. In addition, we identified fuel type conversion patterns and explored the impact of fuel type conversion changes.

There are some limitations of the study. Firstly, household fuel type and the condition of low back pain and neck pain were based on self-reports of the respondents, which may have some recall bias. Secondly, due to data limitations, we did not incorporate the variable of occupation type into the control. Thirdly, we cannot detail the effects of particulate matter pollutants (like $PM_{2.5}$, PM_{10}) and chemical pollutants (like SO_2, NO_2) from solid fuel use on LBP and NP. At the same time, due to the lack of data on other sources of indoor air pollution, this study did not control it. The research data lack the specific duration of fuel exposure and cannot quantify the actual duration or intensity of the exposure. Therefore, further exploration and more validation of the existing results are needed in the future.

Conclusion

We found it has a strong association between household solid fuel and LBP and NP. The use of solid cooking fuel significantly increases the risk of LBP and NP. The use of solid heating fuel also increases the risk of LBP and NP, but the relationship between heating fuel use and the two types of pain still needs to be explored. Conversely, transitioning from solid fuels to cleaner alternatives may mitigate this risk. We suggest that the energy, environment, and health sectors develop and implement effective policies to promote the use of clean energy globally as soon as possible, with the aim of minimizing solid fuels exposures and reducing the mortality and disability rates of vulnerable populations due to LBP and NP.

Abbreviations

CHARLS	China Health and Retirement Longitudinal Study
LBP	Low back pain
NP	Neck pain

Supplementary Information

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Supplementary Material 1

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Author contributions

BL, XS, YW and XZ contributed to the conception and design of the study. BL, XS, YW, QL, YH and MW conducted data reduction, analyses and wrote the manuscript. BL guided the whole process and reviewed the manuscript. All authors read and approved the manuscript before submission.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

CHARLS received approval from the Biomedical Ethics Committee of Peking University (approval number IRB00001052–11015).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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