Vital Surveillances

Rate and Change in Household Solid Fuels Usage Among Residents Aged 40 and Older — China, from 2014–2015 to 2019–2020

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ABSTRACT

Introduction: Solid fuel combustion is a significant source of household air pollution and an important risk factor for chronic obstructive pulmonary disease (COPD). This study presents the rates and change in the use of solid fuels for cooking and heating in China.

Methods: Based on data from the Chinese Chronic Obstructive Pulmonary Disease Surveillance, the research estimated the rates and change of solid fuels usage for cooking and heating from 2014–2015 to 2019–2020 and the rate of primary cooking solid fuels usage in 2019–2020, and analyzed the association between solid fuels usage and COPD.

Results: The rates of solid fuels usage for cooking and heating significantly decreased, dropping from 45.3% to 28.0% and from 33.5% to 23.2%, respectively. Usage rates were higher among rural residents, with 47.2% using it for cooking and 37.7% for heating in 2019-2020. The usage of solid fuels for cooking is associated with increased risk of COPD. Among rural residents, combined usage of biomass and coal for cooking (*OR*=1.29, 95% *CI*: 1.12, 1.48) and using coal as primary fuel for cooking (*OR*=1.18, 95% *CI*: 1.00, 1.38) are associated with higher risk of COPD. The usage of biomass for cooking is associated with an increased risk of COPD in urban residents (*OR*=1.17, 95% *CI*: 1.03, 1.32).

Conclusions: The study demonstrates a significant decline in the use of household solid fuels. Nevertheless, high utilization rates persist among individuals in rural settings and those from lower socioeconomic backgrounds. It is of great public health importance to propose targeted fuel substitution measures for various solid fuels in different regions to reduce the risk of COPD.

Solid fuel combustion is a significant source of household air pollution (HAP) and an important risk factor for chronic obstructive pulmonary disease (COPD) and various health risks(*1*–*3*). Exposure to biomass has been shown to significantly increase the risk of developing COPD (*4*). Globally, HAP from solid fuels is responsible for an estimated loss of 86 million healthy life years and causes around 3.2 million deaths annually (*2*).

The United Nations has established the Sustainable Development Goals (SDGs), specifically SDG7, which aims to ensure universal access to affordable, reliable, sustainable, and modern energy (*5*). In response to economic reforms and rural development programs, there has been a rapid transformation in household energy use in China (*6*). Despite this progress, existing literature only includes data on the use of cooking solid fuels until 2015, and there is a notable deficiency in recent data and information concerning the utilization of solid fuels for heating (*6*–*8*). Additionally, the common practice of "fuel stacking," where individuals use traditional fuels in conjunction with clean fuels, is prevalent in China (*6*,*9*). If evaluations only consider the primary fuel source, the exposure to HAP may be significantly underestimated. Nevertheless, only a limited number of surveys have gathered data on secondary fuel usage.

This study utilized data from the Chinese COPD surveillance to assess the prevalence and changes in the usage of solid fuels for cooking and heating in China between 2014–2015 and 2019–2020. Additionally, the analysis explored the prevalence of primary and partial use of solid fuels for cooking. These insights enhance the accuracy of estimations regarding household solid fuel exposure and inform the development of policies aimed at preventing related diseases.

METHODS

The data analyzed were sourced from the Chinese COPD surveillance, which involved participants aged 40 and above from 125 surveillance points in 31 provinces. This research employed a complex,

multistage, and probability-based sampling methodology. The detailed information about the study design and participants recruitment has been introduced previously (*10*). Following the exclusion of participants lacking fuel-related information, the final analyses comprised data from 75,033 participants from the 2014–2015 survey and 74,556 from the 2019–2020 survey.

Data on general characteristics and utilization of solid fuels were collected through a structured questionnaire managed by trained enumerators. Biomass fuels captured in this analysis included charcoal, wood, crop waste, and animal dung, while coal types consisted of kerosene, paraffin, anthracite, and bitumite. Primary cooking solid fuels use is defined as utilizing solid fuels as the main source of energy for cooking. Cooking solid fuels use encompasses both primary and partial use of biomass or coal for cooking. Similarly, heating solid fuels use is described as utilizing biomass or coal for heating purposes. The Gross Domestic Product (GDP) per capita for the year 2014 and 2019 of each county was sourced from the Statistical Yearbook and categorized into four levels — low, lower-middle, upper-middle, and high — based on median values and quartiles. Geographically, the locations were divided into seven regions: North China, East China, Central China, South China, Southwest China, Northwest China, and Northeast China[*].

The weighted rates and 95% confidence intervals (*CI*s) of solid fuels use across the overall population and various subgroups were calculated. These weights accounted for the survey's sampling scheme and incorporated post-stratification adjustments to align with the demographic structure of China's 2020 Census. Taylor series linearization, accommodating the complex sampling design, was employed to estimate the 95% *CI*s. Differences among subgroups and changes in solid fuels usage from 2014–2015 to 2019–2020 were evaluated using Rao-Scott chi-squared tests. All statistical analyses were performed using SAS software (version 9.4; SAS Institute Inc., Cary, USA), and all tests were two-tailed with a significance threshold set at 0.05.

RESULT

In the 2019–2020 survey, 59.6% of the participants lived in urban areas, 38.0% were aged 60 or older, and 46.0% had attained education up to primary school or less. There were no significant differences in the weighted proportions of these characteristics when compared to the 2014–2015 data (P>0.05). The average GDP per capita increased from 48,872.2 Chinese Yuan (CNY) in 2014–2015 to 64,323.1 CNY in 2019–2020 (P<0.001) (Table 1).

Solid Fuels Use for Cooking and Heating and Its Changes

The usage rates of solid fuels for cooking were 45.3% (95% *CI*: 38.5%, 52.2%) and 28.0% (95% *CI*: 22.6%, 33.5%) for the periods 2014–2015 and 2019–2020, respectively. Similarly, the rates for heating were 33.5% (95% *CI*: 26.2%, 40.7%) and 23.2% (95% *CI*: 17.1%, 29.2%) for the same periods (Table 2). In the years 2019–2020, 38.0% of residents used solid fuels for either cooking or heating, with 15.8% primarily using solid fuels for cooking (Table 2, Supplementary Table S1, available at https://weekly.chinacdc.cn/). Residents from rural areas demonstrated higher usage rates, with 47.2% using solid fuels for cooking, and 37.7% for heating, respectively, in 2019–2020. The elderly, less educated individuals, and those from regions with a lower GDP had elevated usage rates of solid fuels in 2019–2020 (P<0.05) (Table 2, Supplementary Table S2, available at https://weekly.chinacdc.cn/).

The use of solid fuels for cooking decreased by 17.3%. This significant reduction was observed across all regions, with Central China experiencing the most substantial decrease of 33.5%. Similarly, the use of solid fuels for heating fell by 10.3%, although only North China demonstrated a significant decline, dropping from 53.6% to 14.6% (Table 2).

Biomass Use for Cooking and Heating and Its Changes

The prevalence of cooking biomass utilization was recorded at 35.5% (95% *CI*: 29.2%, 41.8%) and 24.0% (95% *CI*: 18.8%, 29.1%), while heating biomass utilization stood at 8.4% (95% *CI*: 5.1%, 11.7%) and 10.1% (95% *CI*: 6.5%, 13.8%) in the periods 2014–2015 and 2019–2020, respectively. Both surveys indicated higher biomass use for cooking and heating in rural areas, among elderly populations, those

[*] North China: Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia. East China: Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, and Shandong. Central China: Henan, Hubei, and Hunan. South China: Guangdong, Guangxi, and Hainan. Southwest China: Chongqing, Sichuan, Guizhou, Yunnan, and Xizang. Northwest China: Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. Northeast China: Liaoning, Heilongjiang, and Jilin.

TABLE 1. Characteristics of participants in the 2014–2015 and 2019–2020 surveys.

Characteristic	2014–2015		2019–2020		*P*
	*N**	%†	*N**	%†	
Area type					
Urban	35,666	59.6	34,236	59.6	0.998
Rural	39,367	40.4	40,320	40.4	
Age, years					
40–49	23,491	29.9	17,635	29.9	1.000
50–59	24,497	32.1	26,325	32.1	
60–69	19,858	21.2	22,766	21.2	
≥70	7,187	16.8	7,830	16.8	
Ethnicity§					
Han	66,768	95.9	66,890	95.2	0.289
Others	8,263	4.1	7,666	4.8	
Educational level§					
Primary school or below	38,687	48.3	37,674	46.0	0.248
Junior high and above	36,344	51.7	36,882	54.0	
Occupation§					
Agriculture	34,937	39.6	31,462	32.1	0.004
Others	40,094	60.4	43,094	67.9	
GDP per capita, CNY, $\bar{X}$ (*S*)¶	48,872.2	26,815.6	64,323.1	36,773.7	<0.001
Area					
East	26,453	42.7	25,874	42.7	1.000
Central	22,186	30.6	22,763	30.6	
West	26,394	26.7	25,919	26.7	
Region					
North China	10,199	15.9	10,182	15.6	0.679
East China	19,173	29.7	19,243	30.7	
Central China	8,978	15.9	9,603	15.3	
South China	7,640	8.7	8,067	6.0	
Southwest China	12,226	15.2	12,117	18.5	
Northwest China	9,027	6.6	8,365	5.6	
Northeast China	7,790	8.0	6,979	8.3	

Abbreviation: GDP=Gross domestic product, CNY=Chinese Yuan, $\bar{X}$=mean, *S*=standard deviation.
* No. of participants was the unweighted number of subcategories denominator.
† The percentages were weighted.
§ Data missing in survey 2014 for Ethnicity (*n*=2), Education level (*n*=2), Occupation (*n*=2).
¶ *P* values for GDP per capita were calculated using *t* test.

with lower educational attainment, and in regions with lower GDP per capita ($P<0.05$).

The use of biomass for cooking decreased by 11.5%, with significant reductions observed in all regions except East China. Specifically, biomass use for heating increased by 9.2% in South China and 7.0% in Central China, while it decreased by 6.2% in Northeast China and 2.8% in North China (Table 3).

Coal Use for Cooking and Heating and Its Changes

The utilization rates of cooking coal decreased from 15.4% (95% *CI*: 10.8%, 19.9%) in 2014–2015 to 6.8% (95% *CI*: 4.6%, 9.0%) in 2019–2020. Likewise, the rates for heating coal use declined from 25.0% (95% *CI*: 18.3%, 31.8%) in 2014–2015 to 13.0%

TABLE 2. Rates and changes in solid fuels use for cooking and heating from 2014–2015 to 2019–2020, and the prevalence of primary solid fuels use for cooking in 2019–2020 among residents aged 40 and older in China, categorized by residence, age, educational level, GDP per capita, and region.

Characteristic	Cooking			Heating			Primary cooking*
	2014–2015	2019–2020	Absolute change (%)†	2014–2015	2019–2020	Absolute change (%)†	2019–2020
	Rate (95% *CI*)	Rate (95% *CI*)		Rate (95% *CI*)	Rate (95% *CI*)		Rate (95% *CI*)
Overall	45.3 (38.5, 52.2)	28.0 (22.6, 33.5)	−17.3§ (−22.1, −12.5)	33.5 (26.2, 40.7)	23.2 (17.1, 29.2)	−10.3§ (−17.1, −3.5)	15.8 (12.2, 19.4)
Residence							
Urban	30.0 (22.7, 37.3)	15.0 (10.6, 19.5)	−15.0§ (−21.0, −8.9)	23.3 (16.7, 29.9)	13.3 (8.2, 18.4)	−10.0§ (−17.0, −3.0)	7.3 (4.8, 9.7)
Rural	67.9 (61.6, 74.2)	47.2 (41.8, 52.6)	−20.7§ (−27.0, −14.5)	48.4 (37.8, 59.02)	37.7 (29.3, 46.1)	−10.7§ (−20.1, −1.3)	28.5 (23.4, 33.5)
χ^2	152.721	–¶		29.463	59.457		495.980
P	<0.001	<0.001		<0.001	<0.001		<0.001
Age, years							
40–49	39.1 (32.5, 45.6)	19.1 (14.8, 23.4)	−20.0§ (−25.2, −14.7)	30.9 (23.9, 37.9)	19.6 (14.1, 25.2)	−11.3§ (−18.1, −4.4)	9.4 (6.7, 12.2)
50–59	43.6 (36.2, 51.0)	26.3 (21.3, 31.3)	−17.4§ (−22.5, −12.2)	34.9 (27.4, 42.4)	23.0 (17.0, 28.9)	−11.9§ (−19.4, −4.4)	12.9 (9.8, 15.9)
60–69	51.1 (42.7, 59.5)	34.2 (26.8, 41.6)	−16.9§ (−22.7, −11.1)	34.2 (26.1, 42.4)	24.3 (17.5, 31.2)	−9.9§ (−17.7, −2.2)	19.9 (15.1, 24.7)
≥70	52.4 (44.7, 60.1)	39.5 (31.6, 47.4)	−13.0§ (−20.8, −5.1)	34.3 (25.7, 42.9)	28.3 (19.9, 36.7)	−6.0 (−14.1, 2.1)	27.7 (21.3, 34.1)
χ^2	37.203	132.462		4.943	17.812		174.460
P	<0.001	<0.001		0.176	<0.001		<0.001
Educational level							
Primary school or below	60.1 (54.1, 66.0)	42.0 (36.9, 47.0)	−18.1§ (−23.3, −12.9)	38.3 (29.7, 46.9)	31.3 (24.1, 38.5)	−7.0§ (−12.9, −1.1)	25.8 (21.6, 29.9)
Junior high or above	31.5 (24.5, 38.6)	16.1 (11.4, 20.9)	−15.4§ (−20.0, −10.8)	28.9 (21.4, 36.4)	16.2 (10.5, 21.8)	−12.7§ (−21.1, −4.3)	7.3 (4.9, 9.7)
χ^2	–¶	–¶		7.124	36.407		–¶
P	<0.001	<0.001		0.008	<0.001		0.031
GDP per capita							
Low	60.1 (51.1, 69.0)	40.1 (29.0, 51.1)	−20.0§ (−33.1, −6.9)	35.2 (20.7, 49.8)	34.1 (20.7, 47.4)	−1.2 (−16.1, 13.8)	25.5 (17.2, 33.8)
Lower-middle	62.1 (51.8, 72.3)	38.4 (28.8, 48.0)	−23.7§ (−34.2, −13.2)	33.6 (18.9, 48.3)	33.4 (19.2, 47.7)	−0.2 (−14.1, 13.8)	21.1 (12.9, 29.2)
Upper-middle	45.4 (32.1, 58.8)	33.9 (28.3, 39.5)	−11.5 (−25.7, 2.7)	39.4 (25.8, 53.0)	30.2 (19.8, 40.6)	−9.2 (−24.7, 6.3)	20.3 (15.7, 24.9)
High	25.1 (15.0, 35.3)	12.2 (5.6, 18.8)	−12.9§ (−20.1, −5.8)	28.3 (13.7, 42.9)	7.1 (0.6, 13.7)	−21.2§ (−36.0, −6.4)	5.0 (1.9, 8.1)
χ^2	34.856	42.219		1.327	20.121		39.621
P	<0.001	<0.001		0.723	<0.001		<0.001
Region							
North China	25.1 (10.9, 39.3)	12.8 (0.0, 25.7)	−12.2§ (−15.7, −8.8)	53.6 (39.9, 67.2)	14.6 (0.5, 28.6)	−39.0§ (−57.7, −20.3)	8.1 (0.0, 18.1)
East China	43.6 (28.9, 58.3)	29.5 (19.5, 39.6)	−14.1§ (−25.9, −2.2)	25.5 (10.8, 40.2)	20.8 (8.6, 33.1)	−4.6 (−12.7, 3.4)	14.1 (7.9, 20.2)
Central China	56.3 (40.8, 71.8)	22.8 (13.4, 32.2)	−33.5§ (−49.5, −17.5)	34.0 (19.0, 49.1)	26.9 (13.6, 40.1)	−7.2 (−19.3, 4.9)	12.5 (7.0, 17.9)
South China	50.9 (31.8, 70.1)	32.6 (16.8, 48.4)	−18.3§ (−28.6, −8.1)	14.0 (3.0, 25.1)	13.3 (1.1, 25.5)	−0.7 (−8.4, 6.9)	15.7 (7.0, 24.3)
Southwest China	51.2 (39.8, 62.6)	37.5 (28.6, 46.4)	−13.6§ (−23.4, −3.9)	22.7 (7.0, 38.3)	16.9 (6.2, 27.7)	−5.7 (−16.4, 5.0)	22.0 (16.0, 28.0)

Continued

Characteristic	Cooking			Heating			Primary cooking*
	2014–2015	2019–2020	Absolute change (%)†	2014–2015	2019–2020	Absolute change (%)†	2019–2020
	Rate (95% *CI*)	Rate (95% *CI*)		Rate (95% *CI*)	Rate (95% *CI*)		Rate (95% *CI*)
Northwest China	47.9 (26.4, 69.4)	30.2 (15.5, 45.0)	−17.7§ (−35.0, −0.4)	47.7 (26.1, 69.3)	50.0 (31.1, 68.8)	2.2 (−19.7, 24.1)	20.4 (7.6, 33.2)
Northeast China	50.8 (31.9, 69.7)	34.6 (16.1, 53.1)	−16.2§ (−26.6, −5.8)	51.7 (34.0, 69.4)	44.0 (22.8, 65.1)	−7.7 (−20.9, 5.5)	26.4 (11.0, 41.8)
χ^2	10.823	11.786		20.267	15.052		10.741
P	0.094	0.067		0.003	0.020		0.097

Note: The difference in the rate of solid fuels use between 2014–2015 and 2019–2020 was tested using Rao−Scott χ^2.
* Primary cooking solid fuels means that using solid fuels as primary energy for cooking.
† Absolute change equals prevalence in 2019 minus prevalence in 2014.
§ means $P<0.05$.
¶ The value of Rao−Scott χ^2 could not be calculated.

(95% *CI*: 8.4%, 17.6%) in 2019–2020. In 2019–2020, higher utilization rates of both cooking and heating coal were observed among rural residents, individuals with lower educational attainment, and regions with lower GDP per capita.

The utilization of cooking coal decreased by 8.6%, with significant reductions observed across all regions except South China and Northwest China. Usage of heating coal also fell by 12.0%, with significant decreases in all regions except Northwest China. North China registered the largest drop, from 50.0% to 13.8% (Table 4).

The Effect of Solid Fuel Usage on COPD

As shown in Table 5, the usage of biomass for cooking is associated with an increased risk of COPD in urban residents (*OR*=1.17, 95% *CI*: 1.03, 1.32). Among rural residents, combined use of biomass and coal fuels for cooking (*OR*=1.29, 95% *CI*: 1.12, 1.48), using coal as primary fuel for cooking (*OR*=1.18 95% *CI*: 1.00, 1.38), and using solid fuels for cooking or heating are associated with higher risk of COPD ($P<0.05$) (Table 5).

DISCUSSION

The usage rate of solid fuels is an important indicator reflecting the prevalence and change of solid fuels exposure, one of the major risk factors for COPD. Understanding the usage rate of solid fuels and its changes in China can provide baseline data for assessing the attributable disease burden of COPD and inform the development of policies to prevent COPD. Solid fuels use significantly contributes to HAP, disease burden, and health degradation in low- and middle-income countries (*1*). This study presents updated, comprehensive, and nationally representative data on the prevalence of solid fuels use for cooking, encompassing both primary and partial usage. According to the World Health Organization (WHO), in 2019, 20.6% of China's population primarily relied on polluting fuels and technologies for cooking (*1*). Our findings show a primary solid fuels use rate of 15.8% among individuals aged 40 and above (*1*), but a total usage rate of 28.0%, indicating that relying solely on primary fuel data may lead to underestimations by nearly 50%. Additionally, the simultaneous use of both traditional and clean stoves and technologies curbs the potential benefits for health and the environment (*11*). Therefore, it is imperative to implement measures that decrease reliance on traditional solid fuel systems and foster new social preferences to facilitate a complete transition to clean energy (*9*).

Data on the use of solid fuels for heating are scarce both globally and within China. The WHO currently only provides data on solid fuels used for cooking, with plans to expand coverage to include heating and lighting fuels starting in 2022 (*1*). Our study indicates that about 60% of household solid fuels consumption can be attributed to heating. Consequently, it is essential to assess the use of solid fuels for heating in studies aimed at estimating disease risks and the burden of HAP exposure. Furthermore, effective interventions, such as clean heating renovations (*12*), must be implemented to reduce the reliance on solid fuels for heating.

The usage rates of solid fuels for cooking and heating decreased by 17.3% and 10.3%, respectively, from 2014–2015 to 2019–2020, exceeding both the global benchmarks and previous trends observed in

TABLE 3. Rates and changes in biomass usage for cooking and heating among residents aged 40 and above in China, from 2014–2015 to 2019–2020, categorized by residence, age, educational level, GDP per capita, and region.

Characteristic	Cooking			Heating		
	2014–2015	2019–2020	Absolute change (%)*	2014–2015	2019–2020	Absolute change (%)*
	Rate (95% *CI*)	Rate (95% *CI*)		Rate (95% *CI*)	Rate (95% *CI*)	
Overall	35.5 (29.2, 41.8)	24.0 (18.8, 29.1)	−11.5† (−15.6, −7.5)	8.4 (5.1, 11.7)	10.1 (6.5, 13.8)	1.7 (−0.7, 4.2)
Residence						
Urban	21.0 (15.2, 26.7)	11.6 (7.8, 15.3)	−9.4† (−14.4, −4.4)	3.8 (1.5, 6.2)	5.8 (2.4, 9.2)	2.0† (−0.1, 4.1)
Rural	56.9 (49.3, 64.6)	42.3 (36.5, 48.1)	−14.6† (−21.7, −7.5)	15.2 (9.6, 20.7)	16.5 (11.4, 21.6)	1.3 (−3.6, 6.3)
χ^2	122.638	–¶		35.743	20.685	
P	<0.001	<0.001		<0.001	<0.001	
Age, years						
40–49	28.4 (23.2, 33.6)	15.0 (11.2, 18.7)	−13.5† (−17.1, −9.8)	6.7 (3.8, 9.5)	7.3 (4.0, 10.5)	0.6 (−1.7, 2.9)
50–59	33.6 (27.0, 40.1)	22.0 (17.4, 26.7)	−11.5† (−15.8, −7.3)	8.1 (4.9, 11.3)	9.4 (6.1, 12.7)	1.3 (−0.9, 3.5)
60–69	42.4 (34.0, 50.8)	30.3 (23.2, 37.3)	−12.1† (−17.5, −6.8)	8.8 (5.7, 11.9)	11.4 (7.4, 15.4)	2.6† (−0.1, 5.3)
≥70	43.1 (35.4, 50.7)	35.7 (27.9, 43.5)	−7.3 (−15.1, 0.4)	11.6 (5.9, 17.3)	15.0 (9.1, 21.0)	3.4 (−2.8, 9.6)
χ^2	58.384	169.536		20.045	35.931	
P	<0.001	<0.001		<0.001	<0.001	
Educational level						
Primary school or below	49.5 (43.3, 55.7)	37.0 (31.7, 42.4)	−12.5† (−17.4, −7.5)	12.4 (7.9, 16.9)	16.1 (10.7, 21.4)	3.7† (−0.2, 7.5)
Junior high or above	22.4 (16.8, 28.1)	12.9 (8.8, 16.9)	−9.6† (−12.9, −6.3)	4.7 (2.4, 7.0)	5.1 (2.9, 7.3)	0.4 (−1.0, 1.9)
χ^2	–¶	–¶		67.479	178.330	
P	<0.001	<0.001		<0.001	<0.001	
GDP per capita						
Low	49.2 (38.5, 59.9)	35.3 (24.1, 46.5)	−13.9 (−27.9, 0.0)	8.8 (3.6, 14.0)	12.0 (6.0, 18.0)	3.2 (−2.5, 9.0)
Lower-middle	49.6 (40.6, 58.7)	30.8 (20.0, 41.5)	−18.8† (−28.2, −9.5)	11.4 (4.9, 17.8)	13.8 (2.3, 25.3)	2.5 (−9.1, 14.0)
Upper-middle	34.7 (23.0, 46.3)	30.0 (24.4, 35.5)	−4.7 (−17.2, 7.9)	14.8 (4.2, 25.5)	17.7 (9.7, 25.7)	2.9 (−9.7, 15.4)
High	18.4 (9.2, 27.6)	10.4 (4.3, 16.6)	−8.0† (−13.6, −2.4)	1.7 (0.0, 3.5)	1.8 (0.0, 3.9)	0.1 (−1.1, 1.2)
χ^2	29.242	28.512		14.032	16.269	
P	<0.001	<0.001		0.003	0.001	
Region						
North China	15.5 (2.5, 28.5)	10.5 (0.0, 21.9)	−5.0† (−8.5, −1.5)	3.6 (0.0, 9.4)	0.8 (0.0, 1.6)	−2.8† (−8.8, 3.2)
East China	33.3 (21.8, 44.7)	25.0 (15.3, 34.6)	−8.3 (−17.1, 0.5)	6.4 (0.0, 14.3)	8.2 (1.0, 15.4)	1.8 (−2.3, 5.9)
Central China	38.1 (23.7, 52.4)	18.1 (9.4, 26.8)	−20.0† (−33.1, −6.8)	13.2 (4.3, 22.0)	20.2 (6.2, 34.2)	7.0† (−0.9, 15.0)
South China	44.4 (26.7, 62.1)	27.6 (13.2, 42.0)	−16.8† (−26.0, −7.5)	4.0 (0.9, 7.1)	13.2 (1.1, 25.3)	9.2† (−1.2, 19.7)
Southwest China	43.9 (31.3, 56.5)	34.0 (24.6, 43.3)	−9.9† (−19.9, 0.0)	7.4 (2.4, 12.4)	9.5 (2.9, 16.1)	2.1 (−4.2, 8.5)
Northwest China	40.6 (19.5, 61.7)	20.7 (9.4, 31.9)	−19.9† (−35.5, −4.3)	6.8 (0.0, 17.5)	6.6 (0.5, 12.7)	−0.2 (−6.2, 5.7)
Northeast China	48.5 (30.0, 67.0)	33.7 (15.2, 52.2)	−14.8† (−26.1, −3.5)	24.2 (15.2, 33.1)	18.0 (6.9, 29.1)	−6.2† (−13.9, 1.5)
χ^2	12.863	13.123		13.992	17.483	
P	0.045	0.041		0.030	0.008	

Note: The difference in the rate of biomass use between 2014–2015 and 2019–2020 was tested using Rao−Scott χ^2.
* Absolute change is calculated as the prevalence in 2019 minus the prevalence in 2014.
† means $P<0.05$.
¶ The value of Rao−Scott χ^2 could not be calculated.

TABLE 4. Rates and changes in coal use for cooking and heating among residents aged 40 and older in China, from 2014–2015 to 2019–2020, categorized by residence, age, educational level, GDP per capita, and region.

Characteristic	Cooking			Heating		
	2014–2015	2019–2020	Absolute change (%)*	2014–2015	2019–2020	Absolute change (%)*
	Rate (95% *CI*)	Rate (95% *CI*)		Rate (95% *CI*)	Rate (95% *CI*)	
Overall	15.4 (10.8, 19.9)	6.8 (4.6, 9.0)	−8.6† (−12.1, −5.1)	25.0 (18.3, 31.8)	13.0 (8.4, 17.6)	−12.0† (−18.6, −5.5)
Residence						
Urban	13.0 (8.2, 17.8)	5.2 (3.1, 7.4)	−7.7† (−11.9, −3.6)	19.5 (13.5, 25.4)	7.5 (3.9, 11.0)	−12.0† (−18.2, −5.9)
Rural	18.9 (13.0, 24.9)	9.1 (6.1, 12.1)	−9.9† (−14.6, −5.1)	33.3 (23.4, 43.1)	21.2 (14.1, 28.4)	−12.0† (−21.5, −2.5)
χ^2	4.647	8.925		13.654	37.030	
P	0.031	0.003		<0.001	0.003	
Age, years						
40-49	15.3 (10.5, 20.0)	6.0 (3.7, 8.4)	−9.2† (−13.3, −5.1)	24.2 (17.8, 30.7)	12.4 (7.9, 16.8)	−11.9† (−18.3, −5.4)
50-59	15.6 (11.0, 20.2)	6.8 (4.7, 8.8)	−8.8† (−12.6, −5.1)	26.8 (19.5, 34.0)	13.6 (8.8, 18.4)	−13.2† (−20.6, −5.8)
60-69	15.2 (10.8, 19.5)	7.1 (4.7, 9.5)	−8.1† (−11.7, −4.5)	25.5 (18.1, 32.8)	12.9 (7.9, 17.9)	−12.6† (−19.7, −5.4)
≥70	15.5 (9.1, 21.8)	7.8 (4.4, 11.2)	−7.7† (−12.9, −2.4)	22.6 (15.3, 30.0)	13.3 (7.6, 18.9)	−9.4† (−15.9, −2.9)
χ^2	0.088	3.444		6.004	1.024	
P	0.993	0.328		0.111	0.796	
Educational level						
Primary school or below	17.7 (12.1, 23.4)	8.9 (6.0, 11.9)	−8.8† (−13.1, −4.5)	25.9 (18.8, 33.0)	15.3 (10.0, 20.5)	−10.7† (−16.4, −4.9)
Junior high or above	13.2 (9.0, 17.3)	5.0 (3.1, 6.8)	−8.2† (−11.7, −4.7)	24.2 (16.8, 31.7)	11.1 (6.4, 15.8)	−13.1† (−21.3, −5.0)
χ^2	6.139	21.611		0.365	4.673	
P	0.013	<0.001		0.546	0.031	
GDP per capita						
Low	17.2 (7.7, 26.7)	8.4 (2.7, 14.1)	−8.8† (−15.6, −2.1)	26.5 (13.8, 39.2)	22.1 (10.4, 33.7)	−4.4 (−18.2, 9.4)
Lower-middle	21.4 (11.3, 31.6)	11.7 (5.9, 17.4)	−9.8† (−19.9, 0.3)	22.2 (10.5, 34.0)	19.6 (8.4, 30.7)	−2.6 (−14.9, 9.6)
Upper-middle	15.7 (4.5, 26.9)	7.5 (3.1, 12.0)	−8.1 (−19.9, 3.6)	24.5 (13.2, 35.9)	12.5 (3.7, 21.3)	−12.0 (−25.1, 1.1)
High	9.9 (3.9, 15.9)	2.8 (1.0, 4.5)	−7.1† (−12.7, −1.6)	26.6 (12.1, 41.0)	5.3 (0.0, 10.8)	−21.2† (−35.8, −6.7)
χ^2	3.813	11.780		0.311	9.067	
P	0.282	0.008		0.958	0.028	
Region						
North China	15.5 (7.8, 23.3)	5.2 (0.0, 10.5)	−10.4† (−14.2, −6.6)	50.0 (36.6, 63.4)	13.8 (0.6, 27.1)	−36.2† (−56.7, −15.8)
East China	16.6 (5.6, 27.6)	7.7 (2.9, 12.4)	−9.0† (−17.5, −0.4)	19.1 (6.8, 31.4)	12.7 (2.6, 22.7)	−6.5 (−14.6, 1.7)
Central China	23.8 (10.9, 36.8)	6.4 (2.2, 10.5)	−17.5† (−31.4, −3.5)	20.9 (8.2, 33.5)	6.6 (1.3, 12.0)	−14.2† (−26.0, −2.4)
South China	11.6 (2.0, 21.3)	8.0 (2.7, 13.3)	−3.6 (−15.3, 8.0)	10.1 (1.3, 18.9)	0.1 (0.0, 0.3)	−10.0† (−19.2, −0.8)
Southwest China	10.8 (0.0, 21.8)	5.8 (0.7, 10.9)	−5.0† (−12.5, 2.5)	15.3 (0.7, 29.9)	7.4 (0.0, 15.8)	−7.8† (−16.4, 0.8)
Northwest China	15.9 (5.3, 26.6)	17.0 (4.4, 29.5)	1.0 (−10.7, 12.7)	40.9 (20.7, 61.1)	43.4 (24.5, 62.2)	2.5 (−18.2, 23.1)
Northeast China	6.1 (1.8, 10.5)	1.9 (0.9, 2.8)	−4.3† (−9.7, 1.2)	27.5 (15.6, 39.4)	26.0 (10.2, 41.8)	−1.5 (−16.5, 13.4)
χ^2	6.185	9.771		25.334	23.772	
P	0.403	0.135		<0.001	0.001	

Note: The difference in rate of coal use between 2014–2015 and 2019–2020 was tested using Rao−Scott χ^2.
* Absolute change is calculated as the prevalence in 2019 minus the prevalence in 2014.
† means $P<0.05$.

TABLE 5. The association of different source of solid fuels usage with chronic obstructive pulmonary disease among residents aged 40 and older in China, 2019-2020, categorized by residence.

Solid fuels usage	Urban		Rural	
	OR (95%*CI*)	*P*	*OR* (95%*CI*)	*P*
Cooking solid fuel usage				
No use(ref)	1.00		1.00	
Biomass	1.17(1.03,1.32)	0.014	0.98(0.90,1.06)	0.641
Coal	0.85(0.69,1.04)	0.105	1.05(0.90,1.21)	0.537
Biomass or Coal	1.06(0.95,1.18)	0.276	1.02(0.94,1.10)	0.636
Biomass and Coal	0.98(0.74,1.30)	0.896	1.29(1.12,1.48)	0.001
Primary solid cooking fuel usage				
No use (ref)	1.00		1.00	
Biomass	1.12(0.97,1.30)	0.115	1.00(0.92,1.08)	0.951
Coal	0.97(0.73,1.28)	0.822	1.18(1.00,1.38)	0.049
household solid fuel usage				
No use (ref)	1.00		1.00	
Biomass	1.10(0.99,1.24)	0.088	1.02(0.94,1.11)	0.663
Coal	1.04(0.92,1.18)	0.535	1.13(1.02,1.24)	0.014
Biomass or Coal	1.06(0.96,1.17)	0.250	1.04(0.96,1.13)	0.308

* The logistic regression model adjusted Age Educational level, BMI, Smoke smog exposure, Family history of lung disease, and exposure to dust or chemicals in the workplace.
Abbreviation: *OR*=odd ratio; *CI*=confidence interval.

China. The Tracking SDG7 initiative indicated a 12% global increase in access to clean cooking fuels between 2010 and 2020 (*13*). Earlier studies documented a 17% reduction in the use of solid fuels for cooking in rural areas from 2000 to 2010 (*12*). A notable decrease in the use of solid fuels for heating was primarily observed in Northern China, likely due to the initiation of clean heating initiatives (coal-to-gas/electricity conversions) beginning in 2017 (*12*).

Significantly, the use of biomass heating, particularly through increased charcoal burning, has risen in Central and South China. This trend is observed in regions where central heating is absent, with charcoal emerging as an important source of heat. However, while charcoal use contributes to $PM_{2.5}$ emissions, it also poses a significant risk of carbon monoxide (CO) poisoning (*14*). Consequently, it is imperative to prioritize understanding of health risks and to implement protective measures against CO poisoning from charcoal use.

In this study, the use of solid fuels was significantly higher in rural areas compared to urban areas, a finding that aligns with global data (*2*) and previous research (*8*). According to the WHO, in 2022, only 14% of urban populations relied on solid fuels for cooking, in contrast to 52% in rural areas (*2*). This urban-rural disparity is likely linked to the differences in fuel and technology availability and affordability (*7*,*15*). Additionally, this study identifies higher rates of solid fuels use among elderly populations, those with lower educational attainment, and regions with lower GDP per capita, which may reflect limited financial capacity and acceptance of modern, cleaner energy technologies (*6*–*7*).

This study is subject to some limitations. It exclusively analyzed households with members aged 40 years and older, potentially leading to an overestimation of the overall solid fuels use rate in China. Furthermore, the data on solid fuel use was gathered through questionnaires, which may introduce recall bias.

In China, the utilization of solid fuels for cooking and heating has substantially declined; however, significant discrepancies between urban and rural areas continue to exist. Individuals of lower socioeconomic status often display higher usage rates of solid fuels. Addressing this issue requires targeted interventions, such as enhancing infrastructure and developing sustainable clean energy systems in rural areas to increase the accessibility of clean fuels (*7*,*15*). Additionally, the implementation of health education initiatives and appropriate subsidy policies can improve

both the willingness and affordability for lower socioeconomic groups to transition to clean fuels (*9*,*15*). It is of great public health importance to proposetargeted fuel substitution measures for various solidfuels in different regions to reduce the risk of COPD.

Conflicts of interest: No conflicts of interest.

Acknowledgements: The research personnel at local Centers for Disease Control and Prevention and hospitals for their diligent efforts in data collection.

Funding: Supported by the Science & Technology Fundamental Resources Investigation Program (Grant No. 2023FY100605), the Chinese Central Government Key Project of Public Health Program, and the National Key Research and Development Program of China (Grant No. 2016YFC1303905).

doi: 10.46234/ccdcw2024.227

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Submitted: January 29, 2024; Accepted: April 28, 2024

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SUPPLEMENTARY TABLE S1. Rates and trends in household solid fuel use from 2014–2015 to 2019–2020 among residents aged 40 and older in China, by residence and region.

Characteristic	Household fuel*		
	2014–2015 (95% *CI*)	2019–2020 (95% *CI*)	Absolute change (%)†
Solid fuel			
Overall	55.9 (49.7, 62.0)	38.0 (31.0, 45.1)	−17.8 (−24.5, −11.2)
Residence			
Urban	39.5 (32.4, 46.7)	22.4 (15.8, 29.0)	−17.1 (−24.6, −9.6)
Rural	80.0 (74.9, 85.2)	61.1 (54.5, 67.7)	−18.9 (−25.9, −11.9)
Region			
North China	55.7 (42.1, 69.2)	18.8 (1.9, 35.7)	−36.9 (−56.4, −17.4)
East China	49.4 (34.2, 64.5)	38.5 (24.9, 52.2)	−10.8 (−20.8, −0.9)
Central China	65.6 (51.4, 79.9)	37.7 (23.3, 52.0)	−28.0 (−44.9, −11.0)
South China	53.6 (33.4, 73.9)	38.6 (20.5, 56.7)	−15.0 (−23.2, −6.8)
Southwest China	57.6 (45.4, 69.8)	44.0 (33.9, 54.1)	−13.6 (−24.5, −2.7)
Northwest China	60.8 (35.3, 86.3)	55.7 (35.3, 76.1)	−5.1 (−25.3, 15.1)
Northeast China	56.3 (36.3, 76.3)	47.5 (24.8, 70.2)	−8.8 (−20.7, 3.0)
Biomass			
Overall	37.8 (31.3, 44.3)	28.6 (22.7, 34.6)	−9.2 (−13.4, −4.9)
Residence			
Urban	22.5 (16.5, 28.6)	15.3 (10.2, 20.4)	−7.3 (−12.5, −2.0)
Rural	60.3 (52.6, 68.0)	48.4 (42.2, 54.5)	−11.9 (−19.1, −4.8)
Region			
North China	15.9 (2.7, 29.1)	10.7 (0.0, 22.3)	−5.2 (−8.7, −1.7)
East China	37.8 (25.4, 50.2)	30.0 (19.0, 41.0)	−7.7 (−17.3, 1.8)
Central China	40.6 (26.4, 54.8)	28.2 (13.4, 43.0)	−12.4 (−28.1, 3.2)
South China	45.0 (27.0, 62.9)	35.3 (17.9, 52.7)	−9.7 (−18.1, −1.3)
Southwest China	45.1 (32.7, 57.5)	36.4 (26.8, 46.0)	−8.7 (−19.1, 1.7)
Northwest China	43.0 (21.1, 65.0)	24.6 (12.8, 36.4)	−18.4 (−33.4, −3.4)
Northeast China	49.6 (31.0, 68.1)	38.5 (19.0, 58.0)	−11.1 (−22.4, 0.2)
Coal			
Overall	32.2 (25.3, 39.2)	16.6 (11.7, 21.4)	−15.7 (−22.4, −8.9)
Residence			
Urban	26.9 (20.2, 33.6)	10.9 (6.8, 15.0)	−16.0 (−22.8, −9.2)
Rural	40.2 (30.4, 50.0)	25.0 (17.9, 32.1)	−15.2 (−24.7, −5.6)
Region			
North China	51.4 (38.0, 64.9)	14.8 (1.1, 28.6)	−36.6 (−57.4, −15.8)
East China	29.6 (15.5, 43.8)	17.3 (7.1, 27.6)	−12.3 (−21.1, −3.5)
Central China	36.4 (21.0, 51.7)	11.8 (4.6, 19.1)	−24.6 (−40.0, −9.1)
South China	18.8 (4.7, 32.9)	8.1 (2.6, 13.5)	−10.7 (−25.2, 3.8)
Southwest China	18.0 (2.7, 33.4)	10.3 (1.7, 18.8)	−7.8 (−17.1, 1.6)
Northwest China	43.1 (22.7, 63.5)	45.4 (25.7, 65.1)	2.3 (−18.9, 23.6)
Northeast China	28.2 (16.3, 40.1)	26.6 (10.9, 42.4)	−1.6 (−16.5, 13.4)

* Household solid fuel use refers to the use of coal or biomass for cooking or heating.
† Absolute change equals prevalence in 2019 minus prevalence in 2014.

SUPPLEMENTARY TABLE S2. Multivariable-adjusted odds ratios for the use of solid fuels among Chinese residents aged 40 years and older, survey 2019–2020.

Fuel type/factors	Cooking		Heating		Household*	
	OR (95% *CI*)	*P*	*OR* (95%*CI*)	*P*	*OR* (95% *CI*)	*P*
Solid fuel						
Residence						
Urban	Ref (1.00)		Ref (1.00)		Ref (1.00)	
Rural	3.65 (2.71, 4.92)	<0.001	3.00 (1.94, 4.63)	<0.001	4.03 (2.81, 5.79)	<0.001
Age,10 years	1.28 (1.19, 1.38)	<0.001	1.08 (0.98, 1.20)	0.130	1.19 (1.10, 1.30)	<0.001
Educational level						
Primary school or below	Ref (1.00)		Ref (1.00)		Ref (1.00)	
Junior high and above	0.42 (0.35, 0.50)	<0.001	0.63 (0.47, 0.83)	0.001	0.43 (0.34, 0.53)	<0.001
GDP per capita	0.66 (0.55, 0.79)	<0.001	0.63 (0.47, 0.85)	0.002	0.61 (0.49, 0.76)	<0.001
Biomass						
Residence						
Urban	Ref (1.00)		Ref (1.00)		Ref (1.00)	
Rural	4.07 (2.96, 5.60)	<0.001	2.21 (1.29, 3.77)	0.004	3.73 (2.66, 5.22)	<0.001
Age,10 years	1.34 (1.24, 1.44)	<0.001	1.15 (1.02, 1.29)	0.024	1.29 (1.19, 1.40)	<0.001
Educational level						
Primary school or below	Ref (1.00)		Ref (1.00)		Ref (1.00)	
Junior high and above	0.41 (0.34, 0.50)	<0.001	0.40 (0.30, 0.52)	<0.001	0.38 (0.31, 0.47)	<0.001
GDP per capita	0.68 (0.56, 0.83)	<0.001	0.74 (0.56, 0.97)	0.032	0.66 (0.54, 0.80)	<0.001
Coal						
Residence						
Urban	Ref (1.00)		Ref (1.00)		Ref (1.00)	
Rural	1.38 (0.94, 2.04)	0.099	2.83 (1.69, 4.75)	<0.001	2.27 (1.45, 3.53)	<0.001
Age,10 years	1.04 (0.90, 1.19)	0.628	1.00 (0.89, 1.13)	0.956	1.00 (0.90, 1.12)	0.975
Educational level						
Primary school or below	Ref (1.00)		Ref (1.00)		Ref (1.00)	
Junior high and above	0.65 (0.50, 0.83)	0.001	1.01 (0.75, 1.36)	0.939	0.88 (0.68, 1.14)	0.332
GDP per capita	0.72 (0.56, 0.92)	0.009	0.64 (0.45, 0.92)	0.015	0.68 (0.50, 0.90)	0.009

* Household solid fuel use means that use coal or biomass for cooking or heating.