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Associations between indoor air pollution for cooking and heating with muscle and sarcopenia in Chinese older population

Zhigang Hu[1,2,3]*, Yufeng Tian[4], Xinyu Song[1,3]*, Fanjun Zeng[1,3] & Ailan Yang[2]

[1]*Department of Respiratory and Critical Care Medicine, The First College of Clinical Medicine Science, China Three Gorges University, Yichang, People's Republic of China;* [2]*Department of Respiratory and Critical Care Medicine, Yichang Central People's Hospital at Zhijiang, Zhijiang, People's Republic of China;* [3]*Department of Respiratory and Critical Care Medicine, Yichang Central People's Hospital, Yichang, People's Republic of China;* [4]*Department of Academic Management, Clinical Research Center, China Three Gorges University, Yichang, People's Republic of China*

Abstract

Background Exposure to air pollution brings the advent effect for various diseases, but study about the relationship between air pollution and ageing is scant. We aimed to determine the associations between household air pollution for cooking and heating with muscle and sarcopenia in Chinese older population by a nationally representative study.
Methods This cross-sectional study included individuals aged 60 and above from the China Health and Retirement Longitudinal Study between 2011 and 2015. The diagnosis of sarcopenia was defined by low muscle mass with low muscle strength and/or reduced physical performance. Generalized additive analyses and dose-dependent analyses with three models were used to assess the effects of different pattern of cooking and heating on muscle and sarcopenia.
Results A total of 8126 Chinese older individuals with predominant male (53.7%) and mean age of 67.3 ± 6.0 years were included in our study. Solid fuel use in cooking showed significant declines in muscle strength (β = −0.424, 95% CI: −0.767, −0.082, $P = 0.01$ in model 3) and mass (β = −0.034, 95% CI: −0.051, −0.017, $P < 0.01$ in model 3), when compared with clean fuel use in cooking, respectively. Solid fuel for heating was correlated with lower muscle strength (β = −0.637, 95% CI: −1.033, −0.241, $P < 0.01$ in model 3) than clean fuel for heating. The joint use of solid fuel for cooking and heating was associated with reduced muscle strength (β = −0.835, 95% CI: −1.306, −0.365, $P < 0.01$ in model 3) and mass (β = −0.038, 95% CI: −0.061, −0.015, $P < 0.01$ in model 3) than clean fuel for cooking and heating. Solid fuel for cooking was associated with significantly increased risk of low muscle strength (adjusted OR = 1.29, 95% CI: 1.11, 1.50, $P < 0.01$ in model 3) and mass (adjusted OR = 1.35, 95% CI: 1.11, 1.61, $P < 0.01$ in model 3), possible sarcopenia (adjusted OR = 1.33, 95% CI: 1.19, 1.48, $P < 0.01$ in model 3) and sarcopenia (adjusted OR = 1.44, 95% CI: 1.21, 1.72, $P < 0.01$ in model 3) compared with clean fuel for cooking. Solid fuel for heating had a significant correlation with low muscle strength (adjusted OR = 1.30, 95% CI: 1.09, 1.56, $P < 0.01$ in model 3) and possible sarcopenia (adjusted OR = 1.49, 95% CI: 1.31, 1.70, $P < 0.01$ in model 3). Dose-dependent manner was shown in the associations between the number of solid fuel with low muscle strength and possible sarcopenia. Clean fuel for cooking and solid fuel for heating was positively associated with the prevalence of possible sarcopenia than clean fuel for cooking and heating (adjusted OR = 1.34, 95% CI: 1.14, 1.57, $P < 0.01$ in model 3).
Conclusions Our findings suggested that solid fuel for cooking and the number of solid fuel use potentially facilitates the onset and progression of muscle loss and sarcopenia.

Keywords Ageing; Air pollution; Muscle; Possible sarcopenia; Sarcopenia; Solid fuel

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**Correspondence to: Zhigang Hu and Xinyu Song, Department of Respiratory and Critical Care Medicine, The First College of Clinical Medicine Science, China Three Gorges University, Yichang 443003, People's Republic of China. Email: hxq910813@163.com; sxy1421@163.com*

Introduction

Accelerating population ageing has become a crucial issue in the world, which may be attributed to the increase in life expectancy and decline in fertility rate.[1] This problem is very prominent in China, where the percentage of population age 65 and above will be expected to exceed 30% by 2050.[1] Normal ageing not only increases susceptibility to many diseases[2] but also is associated with the accelerated loss of muscle mass and function named sarcopenia.[3] Sarcopenia is considered as a progressive and generalized skeletal muscle disorder, which might result in the increase of advent outcomes such as falls, frailty, depression, functional decline, and mortality.[4] The diagnosis of sarcopenia requires the combined measurements of muscle mass, muscle strength, and physical performance. According to the Asian Working Group for Sarcopenia 2019 consensus, sarcopenia is defined by age-related loss of skeletal muscle mass plus loss of muscle strength with or without reduced physical performance.[4] To enhance the consciousness of early identification and intervention, Asian Working Group for Sarcopenia 2019 also introduces the concept of possible sarcopenia defined by low muscle strength and/or reduced physical performance.[4] Recent studies showed that possible sarcopenia declines the ability of physical function[5,6] and increases the risk of cognitive impairment,[7] stroke,[8] and 1 year mortality.[6] Risk factors of developing sarcopenia include co-morbidity, genetic and lifestyle factors operating across the life course. Early prevention and management against risk factors may contribute to delay and reverse the development of sarcopenia and improve patient-related quality-of-life.

In recent decades, the effect of air population on successful ageing has attracted more and more attention. Many epidemiological studies suggested that air pollution has the strong associations with hypertension,[9] cognitive impairment,[10] physical function,[11] depression,[12] and arthritis.[13] Few studies with inconsistent results only assessed the associations between air pollution with muscle mass and strength.[14,15] A cross-sectional study involving 530 older individuals revealed that exposure to particulate matter with aerodynamic diameters $<2.5\ \mu m$ (PM2.5) is associated with the reduction of skeletal muscle mass but has no significant effect on muscle strength.[14] Another study from six low and middle income countries suggested that outdoor (PM2.5) and indoor (solid fuel use for cooking) air pollution both have the negative relationship with muscle strength measured by handgrip strength.[15] Indoor air pollution also includes solid fuel use for heating and cooking. In China, about 450 million individuals still heavily depend on solid fuel use for cooking and heating.[16] Solid fuel use for cooking and heating was estimated to lead to more than 4 million premature deaths each year.[17] However, we did not find the study about the effect of solid fuel use for heating on muscle mass and muscle strength. Meanwhile, whether solid fuel use for heating and cooking influence the risk of sarcopenia still remains to further explore.

Considering that the onset of sarcopenia will gradually increase with population ageing, it is necessary to determine whether solid fuel uses for cooking and heating affect the prevalence of sarcopenia, low muscle strength, and mass. To fill these knowledge gaps, the China Health and Retirement Longitudinal Study (CHARLS) was used to elucidate the associations between indoor air pollution with sarcopenia and muscle by using generalized additive model with binomial or Gaussian regression and dose-dependent analysis.

Methods

Study population

The CHARLS is a large-scale interdisciplinary survey approved by the Biomedical Ethics Review Committee of Peking University and hosted by the National Institute of Development of Peking University and China Research Center for Social Sciences of Peking University. The National School of Development of Peking University collected written informed consent. The CHARLS collected a set of high-quality micro-data representing the families and individuals of the Chinese population aged 45 and above to analyse and promote the interdisciplinary research on the ageing problem. The CHARLS, as a nationally representative study, covered 450 village-level units from 150 county-level units within 28 provinces. The national baseline survey for the CHARLS started from June 2011 and involved 17 708 individuals. The CHARLS performed face-to-face computer-assisted personal interview and physical measurements every 2 years. New individuals were added to the CHARLS at every follow-up. At present, national surveys for the CHARLS have experienced four waves (wave 1 in 2011, wave 2 in 2013, wave 3 in 2015, and wave 4 in 2018). Because the fourth wave of the CHARLS did not provide the data of physical measurements, the individuals were excluded to this study. More detailed description of the CHARLS has been reported elsewhere[18] and via the following link: https://charls.charlsdata.com/pages/Data/2018-charls-wave4/zh-cn.html (accessed on 30 May 2022).

Included participants aged ≥60 years must have detailed information to assess the data of indoor air pollution, muscle, and sarcopenia. Individuals with no data about covariates were excluded from this cross-sectional study.

The assessments of muscle and sarcopenia

In this cross-sectional study, the assessment of muscle included muscle strength and mass. According to previous studies,[19–22] low muscle strength and mass were measured by handgrip strength and an anthropometric equation for the height-adjusted muscle mass (ASM/Ht^2), respectively. Handgrip strength <28.0 kg for men and <18.0 kg for women were categorized as low muscle strength. The equation of ASM/Ht^2 was shown as follows: ASM/Ht^2 = (0.193*body weight + 0.107*height − 4.157*gender − 0.037*age − 2.631)/height^2. This equation was confirmed to well predict muscle mass of Chinese population, same as dual-energy X-ray absorptiometry (DXA) as the gold standard.[19,22] Previous studies fully set the cut-off value of the ASM/Ht^2 to the 20% lowest percentile of the study population.[19–22] In addition, the age reference value of Chinese older population was set to 60-year-old and above. Taken together, $ASM/Ht^2 < 6.84$ kg/m^2 for men and <5.03 kg/m^2 for women were classified as low muscle mass in this study.

As mentioned above, the diagnosis of sarcopenia must comprehensively assess physical performance, muscle strength, and mass. The assessment of physical performance mainly depended on gait speed and 5-time chair stand test. Gait speed < 1.0 m/s and 5-time chair stand test ≥12 s were regarded as reduced physical performance. Referring to previous studies,[20–22] low muscle strength and/or reduced physical performance was deemed as possible sarcopenia. Sarcopenia needed to fulfil low muscle mass with low muscle strength and/or reduced physical performance; meanwhile, low muscle mass with low muscle strength and reduced physical performance were defined as severe sarcopenia.

The assessment of indoor air pollution

The CHARLS collected the data of indoor air pollution for cooking and heating through two structured questionnaires: 'What is the main heating energy source?' and 'What is the main source of cooking fuel?'. In accordance with previous study,[10] solid fuel use for cooking and heating included coal, crop residue, wood, solid charcoal, or others. Meanwhile, natural gas, solar energy, liquefied petroleum gas, electric, or municipal heating were categorized as clean fuel for cooking and heating.

The assessments of covariates

We included the following covariates as potentially confounding factors: sex, age, urban/rural, education level, marital status, body mass index, alcohol, smoking, night sleep duration, napping, peak expiratory flow (PEF), difficult mobility activities, accident, fallen down, and hip fracture and 14 physician-diagnosed chronic diseases (hypertension, dyslipidaemia, hyperglycaemia, cancers, chronic lung diseases, liver diseases, heart diseases, stroke, kidney diseases, digestive diseases, emotional or psychiatric problems, memory-related diseases, arthritis or rheumatism, and asthma). Difficult mobility activities comprised 7-item scores of having any difficulty, which included walking 100 m, climbing several flights of stairs, getting up from a chair, stooping or kneeling or crouching, extending arms up, lifting 5 kg, and picking up a small coin. In our study, difficult mobility activities and PEF were available to evaluate the ability of physical activity. In addition, a meta-analysis demonstrated that depression has a strong association with sarcopenia.[23] The CHALRS assessed depressive symptom by the 10-item Center for Epidemiological Studies–Depression Scale (CES-D10). The detailed assessment and classification of depressive symptom have described in previous study.[24] All categories of included covariates were shown in Table 1.

Statistical analyses

In the first component, the study population was divided into four groups as follows: clean fuel for cooking and heating (Group 1); solid fuel for cooking and clean fuel for heating (Group 2); clean fuel for cooking and solid fuel for heating (Group 3); and solid fuel for cooking and heating (Group 4). We described the categorical variables via counts (percentages) and continuous variables via means and standard deviations, respectively. The differences among each group in categorical variables were estimated by a χ^2 test, while Mann–Whitney *U* test for skewed continuous variables and Student's *t* test or one-way ANOVA for normally distributed continuous variables compared the difference among different groups. The χ^2 goodness-of-fit method determined the normality of the distribution of the data. In the second component of this study, we estimated the associations between different pattern of cooking and heating with muscle (muscle strength and mass) and sarcopenia (possible sarcopenia, sarcopenia, and severe sarcopenia) by using three generalized additive models with binomial regression. In addition, generalized additive models with Gaussian regression was used to determine the relationships between indoor air population with muscle strength and mass when muscle strength and mass were set to continuous variables. We respectively performed three comparisons for the above-mentioned associations, including clean versus solid fuel for cooking, clean versus solid fuel for heating, and four patterns of cooking and heating. Model 1 included individuals' demographic characteristics (sex, age, urban/rural, education levels, marital status, and body mass index), model 2 added physical/behavioural factors (smoking, drinking alcohol, night sleep duration, napping, PEF, and difficulty scores of mobility activities), and model 3 added behavioural factors and 18 above-mentioned co-morbidities. In the third component, dose-dependent analyses with three adjusted models were used to assess the relationships between the number of solid fuel use for cooking and heating with muscle and sarcopenia.

Table 1 The characteristics of our study population in the China Health and Retirement Longitudinal Study

	Clean fuel for cooking and heating	Solid fuel for cooking and clean fuel for heating	Clean fuel for cooking and solid fuel for heating	Solid fuel for cooking and heating	*P*
N	1349	357	2062	4358	
Sex					0.55
Male	724 (53.7%)	202 (56.6%)	1087 (52.7%)	2351 (53.9%)	
Female	625 (46.3%)	155 (43.4%)	975 (47.3%)	2007 (46.1%)	
Age					0.27
60–69 years	894 (66.3%)	246 (68.9%)	1425 (69.1%)	3030 (69.5%)	
70–79 years	382 (28.3%)	96 (26.9%)	554 (26.9%)	1147 (26.3%)	
>80 years	73 (5.4%)	15 (4.2%)	83 (4.0%)	181 (4.2%)	
Urban/rural					<0.01
Rural	445 (33.0%)	226 (63.3%)	1103 (53.5%)	3551 (81.5%)	
Urban	904 (67.0%)	131 (36.7%)	959 (46.5%)	807 (18.5%)	
Education levels					<0.01
Under middle high school	938 (69.5%)	301 (84.3%)	1509 (73.2%)	3838 (88.1%)	
Middle high school	301 (22.3%)	47 (13.2%)	423 (20.5%)	462 (10.6%)	
Above middle high school	110 (8.2%)	9 (2.5%)	130 (6.3%)	58 (1.3%)	
Married status					<0.01
Current unmarried	258 (19.1%)	39 (10.9%)	409 (19.8%)	774 (17.8%)	
Current married	1091 (80.9%)	318 (89.1%)	1653 (80.2%)	3584 (82.2%)	
Body mass index category (kg/m^2)					<0.01
Underweight (<18.5)	81 (6.0%)	16 (4.5%)	159 (7.7%)	446 (10.2%)	
Normal (18.5 to 23.9)	638 (47.3%)	210 (58.8%)	1023 (49.6%)	2574 (59.1%)	
Overweight (24 to 27.9)	463 (34.3%)	89 (24.9%)	671 (32.5%)	1041 (23.9%)	
Obesity (≥28)	167 (12.4%)	42 (11.8%)	209 (10.1%)	297 (6.8%)	
Night sleep duration					<0.01
<6 h	445 (33.0%)	115 (32.2%)	701 (34.0%)	1621 (37.2%)	
6–6.99 h	345 (25.6%)	68 (19.0%)	471 (22.8%)	818 (18.8%)	
7–8 h	469 (34.8%)	140 (39.2%)	749 (36.3%)	1540 (35.3%)	
≥9 h	90 (6.7%)	34 (9.5%)	141 (6.8%)	379 (8.7%)	
Napping					<0.01
0 min	539 (40.0%)	137 (38.4%)	791 (38.4%)	1963 (45.0%)	
1 to 29 min	111 (8.2%)	18 (5.0%)	182 (8.8%)	339 (7.8%)	
30 to 59 min	149 (11.0%)	31 (8.7%)	193 (9.4%)	343 (7.9%)	
60 to 119 min	316 (23.4%)	103 (28.9%)	528 (25.6%)	948 (21.8%)	
≥120 min	234 (17.3%)	68 (19.0%)	368 (17.8%)	765 (17.6%)	
Smoking					<0.01
Yes	535 (39.7%)	158 (44.3%)	864 (41.9%)	2037 (46.7%)	
No	814 (60.3%)	199 (55.7%)	1198 (58.1%)	2321 (53.3%)	
Alcohol					0.01
More than once a month	347 (25.7%)	101 (28.3%)	514 (24.9%)	1205 (27.7%)	
Less than once a month	123 (9.1%)	27 (7.6%)	154 (7.5%)	277 (6.4%)	
Never	879 (65.2%)	229 (64.1%)	1394 (67.6%)	2876 (66.0%)	
Difficult mobility activities					<0.01
Yes	757 (56.1%)	206 (57.7%)	1154 (56%)	2756 (63.2%)	
No	592 (43.9%)	151 (42.3%)	908 (44.0%)	1602 (36.8%)	
PEF(L/min)	280.6 ± 127.9	271.8 ± 114.6	275.2 ± 119.5	262.8 ± 116.1	<0.01
Hypertension					<0.01
Yes	432 (32.0%)	105 (29.4%)	649 (31.5%)	1150 (26.4%)	
No	917 (68.0%)	252 (70.6%)	1413 (68.5%)	3208 (73.6%)	

(*Continues*)

Table 1 (continued)

	Clean fuel for cooking and heating	Solid fuel for cooking and clean fuel for heating	Clean fuel for cooking and solid fuel for heating	Solid fuel for cooking and heating	*P*
Dyslipidaemia					<0.01
Yes	174 (12.9%)	30 (8.4%)	242 (11.7%)	342 (7.8%)	
No	1175 (87.1%)	327 (91.6%)	1820 (88.3%)	4016 (92.2%)	
Hyperglycaemia					<0.01
Yes	104 (7.7%)	24 (6.7%)	152 (7.4%)	238 (5.5%)	
No	1245 (92.3%)	333 (93.3%)	1910 (92.6%)	4120 (94.5%)	
Cancers					<0.01
Yes	15 (1.1%)	8 (2.2%)	16 (0.8%)	27 (0.6%)	
No	1334 (98.9%)	349 (97.8%)	2046 (99.2%)	4331 (99.4%)	
Chronic lung diseases					<0.01
Yes	149 (11.0%)	36 (10.1%)	230 (11.2%)	594 (13.6%)	
No	1200 (89.0%)	321 (89.9%)	1832 (88.8%)	3764 (86.4%)	
Liver diseases					0.28
Yes	54 (4.0%)	21 (5.9%)	77 (3.7%)	187 (4.3%)	
No	1295 (96.0%)	336 (94.1%)	1985 (96.3%)	4171 (95.7%)	
Heart diseases					0.01
Yes	199 (14.8%)	35 (9.8%)	319 (15.5%)	583 (13.4%)	
No	1150 (85.2%)	322 (90.2%)	1743 (84.5%)	3775 (86.6%)	
Stroke					0.01
Yes	49 (3.6%)	5 (1.4%)	42 (2.0%)	106 (2.4%)	
No	1300 (96.4%)	352 (98.6%)	2020 (98.0%)	4252 (97.6%)	
Kidney diseases					0.20
Yes	81 (6.0%)	18 (5.0%)	130 (6.3%)	312 (7.2%)	
No	1268 (94.0%)	339 (95.0%)	1932 (93.7%)	4046 (92.8%)	
Digestive diseases					0.10
Yes	283 (21.0%)	86 (24.1%)	456 (22.1%)	1041 (23.9%)	
No	1066 (79.0%)	271 (75.9%)	1606 (77.9%)	3317 (76.1%)	
Emotional, nervous, or psychiatric problems					0.5
Yes	10 (0.7%)	5 (1.4%)	24 (1.2%)	53 (1.2%)	
No	1339 (99.3%)	352 (98.6%)	2038 (98.8%)	4305 (98.8%)	
Memory-related diseases					0.27
Yes	20 (1.5%)	4 (1.1%)	44 (2.1%)	68 (1.6%)	
No	1329 (98.5%)	353 (98.9%)	2018 (97.9%)	4290 (98.4%)	
Arthritis or rheumatism					<0.01
Yes	421 (31.2%)	130 (36.4%)	678 (32.9%)	1654 (38.0%)	
No	928 (68.8%)	227 (63.6%)	1384 (67.1%)	2704 (62.0%)	
Asthma					0.08
Yes	43 (3.2%)	19 (5.3%)	97 (4.7%)	207 (4.7%)	
No	1306 (96.8%)	338 (94.7%)	1965 (95.3%)	4151 (95.3%)	
Accident					0.6
Yes	79 (5.9%)	20 (5.6%)	129 (6.3%)	293 (6.7%)	
No	1270 (94.1%)	337 (94.4%)	1933 (93.7%)	4065 (93.3%)	
Fallen down					0.05
Yes	215 (15.9%)	68 (19.0%)	335 (16.2%)	802 (18.4%)	
No	1134 (84.1%)	289 (81.0%)	1727 (83.8%)	3556 (81.6%)	
Hip fracture					0.726
Yes	13 (1.0%)	6 (1.7%)	23 (1.1%)	49 (1.1%)	
No	1336 (99.0%)	351 (98.3%)	2039 (98.9%)	4309 (98.9%)	

(*Continues*)

Table 1 (continued)

	Clean fuel for cooking and heating	Solid fuel for cooking and clean fuel for heating	Clean fuel for cooking and solid fuel for heating	Solid fuel for cooking and heating	*P*
Depression					<0.01
No depression	902 (66.9%)	238 (66.7%)	1346 (65.3%)	2382 (54.7%)	
Depression	418 (31.0%)	109 (30.5%)	662 (32.1%)	1763 (40.5%)	
Severe depression	29 (2.1%)	10 (2.8%)	54 (2.6%)	213 (4.9%)	
Low muscle strength					<0.01
Yes	148 (11.0%)	52 (14.6%)	259 (12.6%)	732 (16.8%)	
No	1201 (89.0%)	305 (85.4%)	1803 (87.4%)	3626 (83.2%)	
Low muscle mass					<0.01
Yes	198 (14.7%)	61 (17.1%)	338 (16.4%)	1035 (23.7%)	
No	1151 (85.3%)	296 (82.9%)	1724 (83.6%)	3323 (76.3%)	
Possible sarcopenia					<0.01
Yes	422 (31.3%)	121 (33.9%)	756 (36.7%)	1946 (44.7%)	
No	927 (68.7%)	236 (66.1%)	1306 (63.3%)	2412 (55.3%)	
Sarcopenia					<0.01
Yes	187 (13.9%)	61 (17.1%)	316 (15.3%)	1008 (23.1%)	
No	1,162 (86.1%)	296 (82.9%)	1746 (84.7%)	3,350 (76.9%)	
Severe sarcopenia					<0.01
Yes	50 (3.7%)	19 (5.3%)	88 (4.3%)	285 (6.5%)	
No	1299 (96.3%)	338 (94.7%)	1974 (95.7%)	4,073 (93.5%)	

PEF, peak expiratory flow. No depression, CESD-10 $<$ 10 scores; depression, CESD-10 = 11–19 scores; severe depression, CESD $\geq$ 20 scores.

We performed all statistical analyses by using Empower(R) (www. empowerstats.com; X&Y solutions, Inc., Boston MA). Odds ratios (ORs) with 95% confidence intervals (CIs) exhibited the strength of all associations, and a two tailed $P < 0.05$ was considered statistically significant.

Results

Basic characteristics of the study population

A total of 8126 individuals aged 60 and above were included in our study in three waves of the CHARLS. The flow diagram of study population was shown in Figure 1. The mean age of all individuals in this study was 67.3 ± 6.0 years, with predominant male (53.7%), rural (65.5%), and current married (81.8%). The proportion of individuals with never smoking and drinking alcohol was 55.8% and 66.2%, respectively. More than half older individuals had the habit of napping. Of the included people, 40% had no difficult mobility activity. The mean values of body mass index and PEF were 23.0 ± 3.8 kg/m^2 and 269.3 ± 119.1 L/min, respectively. Solid fuel for cooking was used by 4715 individuals (58%), while 6420 individuals (79%) used solid fuel for heating. Only 1349 (16.6%) older individuals used clean fuel for both cooking and heating; meanwhile, the amount of older individuals using two solid fuels for both cooking and heating was 4358 (53.6%). A total of 1191 (14.7%) individuals were associated with low muscle strength. The prevalence of possible sarcopenia, sarcopenia, and severe sarcopenia was 39.9%, 19.3%, and 5.4%, respectively. Solid fuel for cooking was associated with higher scores of depressive symptoms (19.4 ± 5.3 scores vs. 18.3 ± 5.3 scores, $P < 0.01$) and the lower values of handgrip strength (30.2 ± 9.6 kg vs. 31.3 ± 9.6 kg, $P < 0.01$), body mass index (22.6 ± 3.7 kg/m^2 vs. 23.6 ± 3.8 kg/m^2, $P < 0.01$), and PEF (263.5 ± 116.0 L/min vs. 277.3 ± 122.9 L/min, $P < 0.01$) compared with clean fuel for cooking. Higher proportions of rural (80.1% vs. 45.5%, $P < 0.01$), chronic lung diseases (13.4% vs. 11.4%, $P < 0.01$), severe depression (4.7% vs. 2.4%, $P < 0.01$), and difficult mobility activity (62.8% vs. 56%, $P < 0.01$) were shown in solid fuel for cooking than clean fuel for cooking. Similar results also were shown in solid fuel for heating than clean fuel for heating. Table 1 summarizes the basic characteristics of four different pattern for cooking and heating. Overall, the prevalence of three types of sarcopenia and low muscle gradually increased with the increasing number of solid fuel for cooking and heating.

Associations between indoor air pollution and muscle

Three adjusted analyses demonstrated that whether solid fuel for cooking (adjusted OR = 1.29, 95% CI: 1.11, 1.50, $P < 0.01$ in model 3) or solid fuel for heating (adjusted

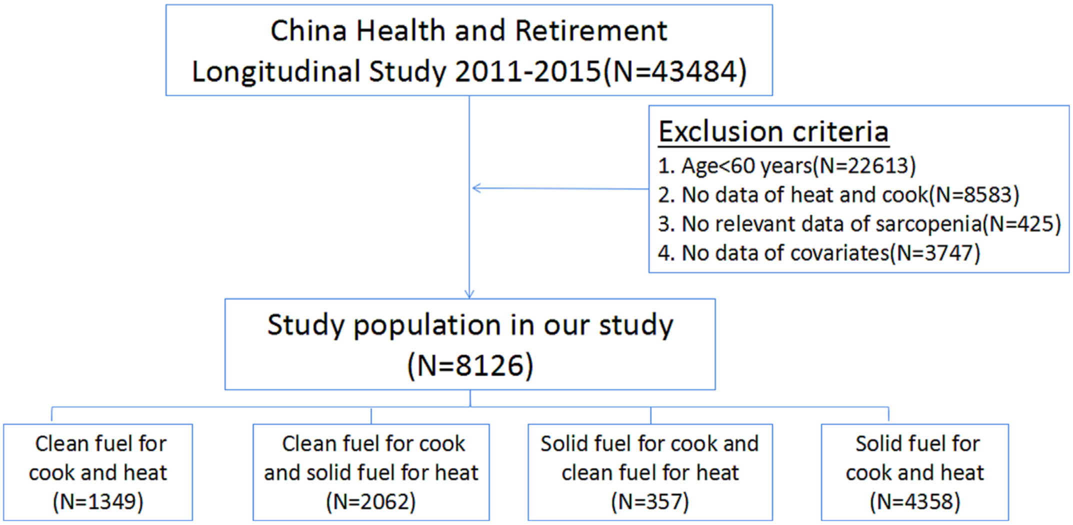

Figure 1 The flow diagram of study population.

OR = 1.30, 95% CI: 1.09, 1.56, $P < 0.01$ in model 3) both are associated with the increased risk of low muscle strength compared with clean fuel (see Table 2 and Figure S1). The highest prevalence of low muscle strength among four pattern for cooking and heating was shown in solid fuel for cooking and heating, followed by solid fuel for cooking and clean fuel for heating, clean fuel for cooking and solid fuel for heating, and clean fuel for cooking and heating. Solid fuel for cooking and heating had the higher prevalence of low muscle strength than clean fuel for cooking and heating (adjusted OR = 1.51, 95% CI: 1.21, 1.87, $P < 0.01$ in model 3). Dose-dependent analysis suggested that the number of solid fuel for cooking and heating is positively associated with the prevalence of low muscle strength (see Table 2 and Figure 2A).

Compared with clean fuel, solid fuel for cooking (adjusted OR = 1.35, 95% CI: 1.14, 1.61, $P < 0.01$ in model 3) but not solid fuel for heating (adjusted OR = 1.11, 95% CI: 0.9, 1.36 in model 3, $P = 0.35$) was more likely to suffer from low muscle mass after adjustment for all included confounding variables. When Chinese older population simultaneously used two solid fuels for cooking and heating, the prevalence of low muscle mass significantly increased (No vs. Two, adjusted OR = 1.32, 95% CI: 1.03, 1.69, $P < 0.01$ in model 3).

When muscle strength and mass were considered continuous variables, all three models showed that solid fuel for cooking was associated with significantly lower values of handgrip strength ($\beta = -0.424$, 95% CI: -0.767, -0.082, $P = 0.01$ in model 3) and ASM/Ht^2 ($\beta = -0.034$, 95% CI: -0.051, -0.017, $P < 0.01$ in model 3) compared with clean fuel for cooking. Dose-dependent decrease in the values of handgrip strength and ASM/Ht^2 came with the rising number of solid fuel for cooking and heating (see Figure 2B,C). Solid fuel for cooking and clean fuel for heating in handgrip strength showed no significant increase ($\beta = -0.406$, 95% CI: -1.241, 0.430, $P = 0.34$ in model 3) compared with clean fuel for cooking and heating, while clean fuel for cooking and solid fuel for heating also had no significant difference ($\beta = -0.010$, 95% CI: -0.034, 0.015, $P = 0.44$ in model 3) in muscle mass than reference group. When the pattern for cooking and heating was divided into four groups, solid fuel for cooking and solid fuel for heating seemingly had relatively large effects on muscle mass and muscle strength, respectively (see Table 3).

Associations between indoor air pollution and sarcopenia

As shown in Table 4 and Figure 2, the prevalence of possible sarcopenia was accompanied by the significant rise in solid fuel for cooking (adjusted OR = 1.33, 95% CI: 1.19, 1.48, $P < 0.01$ in model 3) and solid fuel for heating (adjusted OR = 1.49, 95% CI: 1.31, 1.70, $P < 0.01$ in model 3) than reference group (clean fuel). Solid fuel for cooking and heating (adjusted OR = 1.66, 95% CI: 1.43, 1.94, $P < 0.01$ in model 3) and clean fuel for cooking and solid fuel for heating (adjusted OR = 1.34, 95% CI: 1.14, 1.57 in model 3) showed significantly higher prevalence of possible sarcopenia than clean fuel for cooking and heating (see Figure S2). The prevalence of possible sarcopenia was found to have a significantly dose-dependent manner with the number of solid fuel for cooking and heating (see Figure 2D).

Chinese older individuals using solid fuel for cooking were more likely to experience sarcopenia than those using clean fuel for cooking (adjusted OR = 1.44, 95% CI: 1.21, 1.72, $P < 0.01$ in model 3). Solid fuel for heating was associated with an upward trend but not statistical significance (adjusted

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Table 2 Associations between household air pollution for heating and cooking with muscle strength and mass

	Model 1		Model 2		Model 3	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
The prevalence of low muscle strength						
Cooking						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.35 (1.17, 1.56)	<0.01	1.33 (1.15, 1.54)	<0.01	1.29 (1.11, 1.50)	<0.01
Heating						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.30 (1.09, 1.55)	<0.01	1.30 (1.09, 1.56)	<0.01	1.30 (1.09, 1.56)	<0.01
Cooking and heating						
No solid fuel	Ref		Ref		Ref	
One solid fuel	1.24 (0.99, 1.54)	0.06	1.24 (1.01, 1.58)	<0.05	1.28 (1.02, 1.60)	<0.05
Two solid fuels	1.53 (1.24, 1.89)	<0.01	1.56 (1.24, 1.90)	<0.01	1.51 (1.21, 1.87)	<0.01
Cooking and heating						
Clean fuel for cooking and heating	Ref		Ref		Ref	
Solid fuel for cooking and clean fuel for heating	1.39 (0.97, 1.98)	0.07	1.41 (0.98, 2.03)	0.06	1.40 (0.97, 2.02)	0.07
Clean fuel for cooking and solid fuel for heating	1.21 (0.97, 1.51)	0.1	1.21 (0.98, 1.56)	0.07	1.25 (0.99, 1.58)	0.06
Solid fuel for cooking and heating	1.54 (1.24, 1.89)	<0.01	1.54 (1.24, 1.91)	<0.01	1.51 (1.21, 1.87)	<0.01
The prevalence of low muscle mass						
Cooking						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.37 (1.15, 1.62)	<0.01	1.37 (1.15, 1.62)	<0.01	1.35 (1.14, 1.61)	<0.01
Heating						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.11 (0.90, 1.36)	0.31	1.11 (0.91, 1.37)	0.3	1.11 (0.90, 1.36)	0.35
Cooking and heating						
No solid fuel	Ref		Ref		Ref	
One solid fuel	0.97 (0.75, 1.26)	0.84	0.99 (0.76, 1.29)	0.95	1.00 (0.76, 1.30)	0.97
Two solid fuels	1.31 (1.02, 1.68)	<0.05	1.32 (1.03, 1.69)	<0.05	1.32 (1.03, 1.69)	<0.05
Cooking and heating						
Clean fuel for cooking and heating	Ref		Ref		Ref	
Solid fuel for cooking and clean fuel for heating	1.21 (0.81, 1.82)	0.37	1.24 (0.82, 1.88)	0.3	1.25 (0.83, 1.90)	0.28
Clean fuel for cooking and solid fuel for heating	0.93 (0.71, 1.22)	0.6	0.95 (0.72, 1.24)	0.69	0.95 (0.72, 1.25)	0.7
Solid fuel for cooking and heating	1.31 (1.03, 1.68)	<0.05	1.32 (1.03, 1.70)	<0.05	1.31 (1.02, 1.68)	<0.05

Model 1 adjusted the following variables: sex, age, region, urban/rural, married status, education levels, and body mass index. Model 2 adjusted the following variables: sex, age, region, urban/rural, education levels, married status, education levels, body mass index, smoking, alcohol, night sleep duration, napping, difficult mobility activities and peak expiratory flow. Model 3 adjusted the following variables: sex, age, region, urban/rural, education levels, married status, education levels, body mass index, smoking, alcohol, night sleep duration, napping, difficult mobility activities, peak expiratory flow, accident, fallen down, hip fracture, depression, hypertension, dyslipidaemia, hyperglycaemia, cancer, chronic lung diseases, liver diseases, heart diseases, stroke, kidney diseases, digestive diseases, emotional or psychiatric problems, memory-related diseases, arthritis or rheumatism, and asthma.

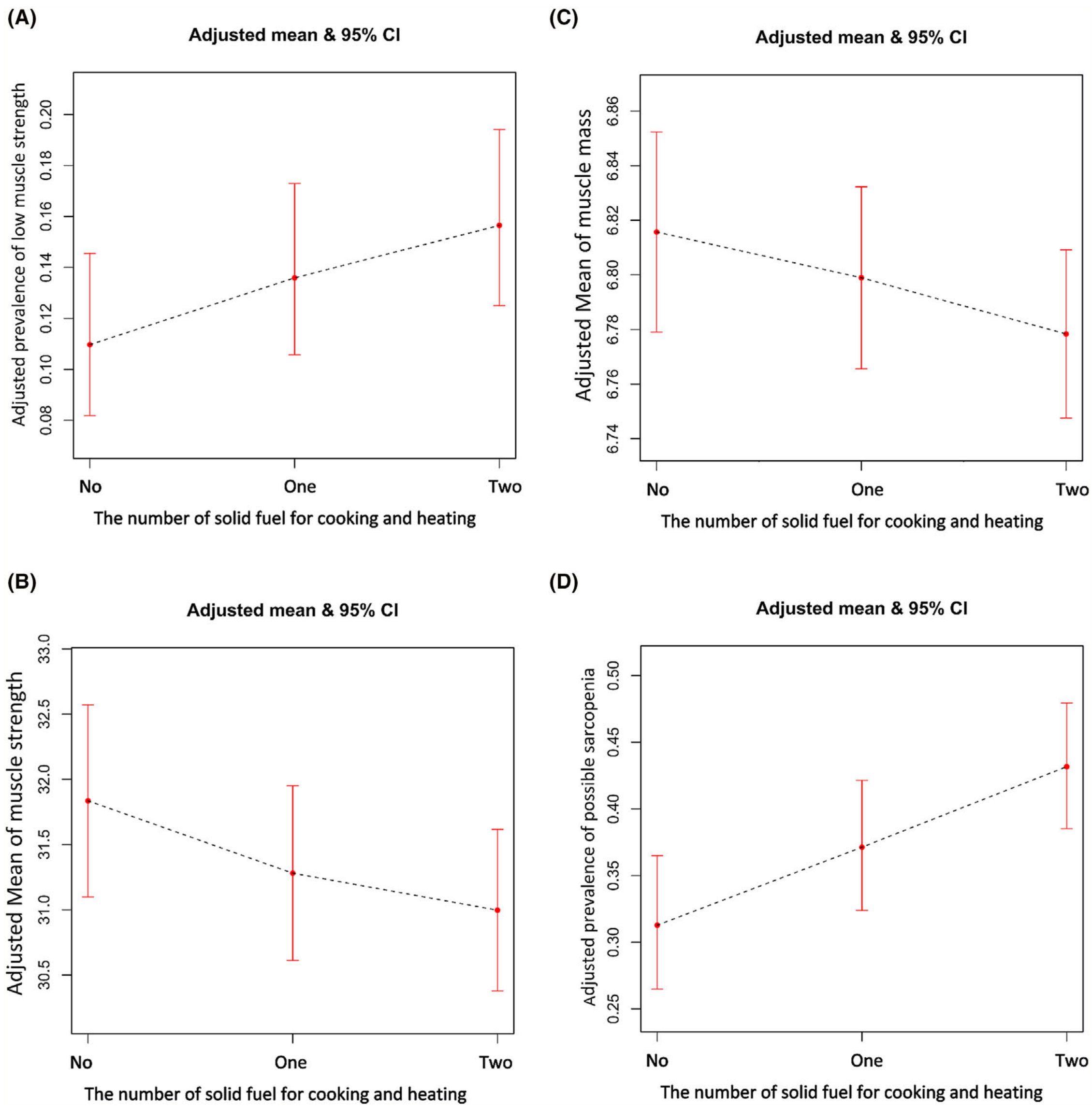

Figure 2 Dose-dependent analyses: (A) The association between the number of solid fuel for cooking and heating with adjusted prevalence of low muscle strength; (B) the association between the number of solid fuel for cooking and heating with the value of muscle strength; (C) the association between the number of solid fuel for cooking and heating with the value of muscle mass; (D) the association between the number of solid fuel for cooking and heating with adjusted prevalence of possible sarcopenia.

OR = 1.10, 95% CI: 0.89, 1.36, P = 0.39) in the prevalence of sarcopenia than clean fuel for heating in the fully adjusted models. Dose-dependent analysis demonstrated that two solid fuels for cooking and heating is correlated with the higher risk of sarcopenia than no solid fuel for cooking and heating (adjusted OR = 1.36, 95% CI: 1.06, 1.76, $P < 0.01$ in model 3).

The prevalence of severe sarcopenia has increased somewhat together with the use and number of solid fuel for cooking and heating. However, the differences in the prevalence among each group did not show statistical significance in all analyses (see Tables 2 and 4).

Discussion

Our study simultaneously assessed the separate and joint effects of solid fuel for cooking and heating on muscle and sarcopenia in Chinese older population on the basis of a nationally representative study. Solid fuel for cooking and two solid fuels for cooking and heating had the strong associations with possible sarcopenia, sarcopenia, low muscle strength, and mass. The number of solid fuel for cooking and heating even showed significantly dose-dependent manner with the prevalence of possible sarcopenia and low muscle strength. In addition, solid fuel for heating was associated with the in-

Table 3 Associations between household air pollution for heating and cooking with muscle strength and mass

	Model 1		Model 2		Model 3	
	β (95% CI)	*P*	β (95% CI)	*P*	β (95% CI)	*P*
Muscle strength						
Cooking						
Clean fuel	Ref		Ref		Ref	
Solid fuel	−0.592 (−0.943, −0.242)	<0.01	−0.465 (−0.805, −0.124)	<0.01	−0.424 (−0.767, −0.082)	0.01
Heating						
Clean fuel	Ref		Ref		Ref	
Solid fuel	−0.742 (−1.15, −0.334)	<0.01	−0.646 (−1.042, −0.250)	<0.01	−0.637 (−1.033, −0.241)	<0.01
Cooking and heating						
Clean fuel for cooking and heating	Ref		Ref		Ref	
Solid fuel for cooking and clean fuel for heating	−0.51 (−1.372, 0.352)	0.25	−0.433 (−1.269, 0.403)	0.31	−0.406 (−1.241, 0.430)	0.34
Clean fuel for cooking and solid fuel for heating	−0.609 (−1.116, −0.102)	0.02	−0.567 (−1.059, −0.075)	0.02	−0.579 (−1.070, −0.088)	0.02
Solid fuel for cooking and heating	−1.03 (−1.514, −0.546)	<0.01	−0.869 (−1.339, −0.398)	<0.01	−0.835 (−1.306, −0.365)	<0.01
Cooking and heating						
No solid fuel	Ref		Ref		Ref	
One solid fuel	−0.595 (−1.088, −0.102)	0.02	−0.548 (−1.026, −0.069)	0.02	−0.554 (−1.032, −0.076)	0.02
Two solid fuels	−1.031 (−1.515, −0.547)	<0.01	−0.87 (−1.34, −0.40)	<0.01	−0.838 (−1.308, −0.367)	<0.01
Muscle mass						
Cooking						
Clean fuel	Ref		Ref		Ref	
Solid fuel	−0.038 (−0.055, −0.021)	<0.01	−0.035 (−0.052, −0.018)	<0.01	−0.034 (−0.051, −0.017)	<0.01
Heating						
Clean fuel	Ref		Ref		Ref	
Solid fuel	−0.014 (−0.034, 0.006)	0.16	−0.012 (−0.032, 0.008)	0.23	−0.013 (−0.033, 0.007)	0.21
Cooking and heating						
Clean fuel for cooking and heating	Ref		Ref		Ref	
Solid fuel for cooking and clean fuel for heating	−0.061 (−0.103, −0.019)	<0.01	−0.060 (−0.102, −0.019)	<0.01	−0.060 (−0.101, −0.018)	<0.01
Clean fuel for cooking and solid fuel for heating	−0.008 (−0.033, 0.017)	0.52	−0.008 (−0.033, 0.016)	0.52	−0.010 (−0.034, 0.015)	0.44
Solid fuel for cooking and heating	−0.042 (−0.065, −0.018)	<0.01	−0.038 (−0.062, −0.015)	<0.01	−0.038 (−0.061, −0.015)	<0.01
Cooking and heating						
No solid fuel	Ref		Ref		Ref	
One solid fuel	−0.016 (−0.040, 0.008)	0.20	−0.016 (−0.039, 0.008)	0.20	−0.017 (−0.041, 0.007)	0.17
Two solid fuels	−0.041 (−0.064, −0.017)	<0.01	−0.038 (−0.061, −0.014)	<0.01	−0.037 (−0.061, −0.014)	<0.01

Model 1 adjusted the following variables: sex, age, region, urban/rural, married status, education levels, and body mass index. Model 2 adjusted the following variables: sex, age, region, urban/rural, education levels, married status, education levels, body mass index, smoking, alcohol, night sleep duration, napping, difficult mobility activities and peak expiratory flow. Model 3 adjusted the following variables: sex, age, region, urban/rural, education levels, married status, education levels, body mass index, smoking, alcohol, night sleep duration, napping, difficult mobility activities, peak expiratory flow, accident, fallen down, hip fracture, depression, hypertension, dyslipidaemia, hyperglycaemia, cancer, chronic lung diseases, liver diseases, heart diseases, stroke, kidney diseases, digestive diseases, emotional or psychiatric problems, memory-related diseases, arthritis or rheumatism, and asthma.

Table 4 Associations between household air pollution for heating and cooking with sarcopenia

	Model 1		Model 2		Model 3	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
The prevalence of possible sarcopenia						
Cooking						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.41 (1.27, 1.56)	<0.01	1.35 (1.22, 1.50)	<0.01	1.33 (1.19, 1.48)	<0.01
Heating						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.53 (1.35, 1.73)	<0.01	1.50 (1.32, 1.70)	<0.01	1.49 (1.31, 1.70)	<0.01
Cooking and heating						
No solid fuel	Ref		Ref		Ref	
One solid fuel	1.29 (1.11, 1.50)	<0.01	1.29 (1.11, 1.51)	<0.01	1.30 (1.11, 1.52)	<0.01
Two solid fuels	1.78 (1.52, 2.03)	<0.01	1.69 (1.45, 1.96)	<0.01	1.67 (1.43, 1.94)	<0.01
Cooking and heating						
Clean fuel for cooking and heating	Ref		Ref		Ref	
Solid fuel for cooking and clean fuel for heating	1.12 (0.86, 1.45)	0.39	1.10 (0.84, 1.44)	0.48	1.10 (0.83, 1.43)	0.52
Clean fuel for cooking and solid fuel for heating	1.32 (1.13, 1.54)	<0.01	1.33 (1.13, 1.55)	<0.01	1.34 (1.14, 1.57)	<0.01
Solid fuel for cooking and heating	1.75 (1.52, 2.03)	<0.01	1.69 (1.45, 1.96)	<0.01	1.66 (1.43, 1.94)	<0.01
The prevalence of sarcopenia						
Cooking						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.46 (1.23, 1.74)	<0.01	1.46 (1.22, 1.74)	<0.01	1.44 (1.21, 1.72)	<0.01
Heating						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.11 (0.90, 1.36)	0.33	1.11 (0.90, 1.36)	0.35	1.10 (0.89, 1.35)	0.39
Cooking and heating						
No solid fuel	Ref		Ref		Ref	
One solid fuel	0.97 (0.75, 1.27)	0.83	0.99 (0.76, 1.30)	0.97	1.00 (0.76, 1.31)	0.98
Two solid fuels	1.37 (1.07, 1.76)	<0.05	1.38 (1.07, 1.77)	<0.05	1.36 (1.06, 1.76)	<0.05
Cooking and heating						
Clean fuel for cooking and heating	Ref		Ref		Ref	
Solid fuel for cooking and clean fuel for heating	1.34 (0.89, 2.01)	0.16	1.39 (0.92, 2.11)	0.11	1.40 (0.92, 2.12)	0.11
Clean fuel for cooking and solid fuel for heating	0.91 (0.69, 1.19)	0.48	0.92 (0.70, 1.22)	0.58	0.92 (0.70, 1.22)	0.58
Solid fuel for cooking and heating	1.38 (1.07, 1.76)	<0.05	1.38 (1.07, 1.76)	<0.05	1.37 (1.06, 1.76)	<0.05
The prevalence of severe sarcopenia						
Cooking						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.21 (0.96, 1.54)	0.11	1.25 (0.98, 1.59)	0.07	1.22 (0.96, 1.56)	0.1
Heating						
Clean fuel	Ref		Ref		Ref	
Solid fuel	1.09 (0.81, 1.47)	0.57	1.12 (0.83, 1.53)	0.44	1.16 (0.85, 1.57)	0.35
Cooking and heating						
No solid fuel	Ref		Ref		Ref	
One solid fuel	1.16 (0.80, 1.70)	0.43	1.23 (0.84, 1.81)	0.29	1.28 (0.87, 1.89)	0.21
Two solid fuels	1.28 (0.90, 1.82)	0.18	1.35 (0.94, 1.94)	0.1	1.37 (0.95, 1.97)	0.09
Cooking and heating						

(*Continues*)

Table 4 (continued)

	Model 1		Model 2		Model 3	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Clean fuel for cooking and heating	Ref		Ref		Ref	
Solid fuel for cooking and clean fuel for heating	1.52 (0.85, 2.74)	0.16	1.67 (0.92, 3.03)	0.09	1.65 (0.91, 3.02)	0.1
Clean fuel for cooking and solid fuel for heating	1.10 (0.75, 1.63)	0.62	1.16 (0.78, 1.73)	0.47	1.21 (0.81, 1.82)	0.34
Solid fuel for cooking and heating	1.28 (0.90, 1.82)	0.18	1.35 (0.94, 1.94)	0.1	1.37 (0.95, 1.97)	0.09

Model 1 adjusted the following variables: sex, age, region, urban/rural, married status, education levels, and body mass index. Model 2 adjusted the following variables: sex, age, region, urban/rural, education levels, married status, education levels, body mass index, smoking, alcohol, night sleep duration, napping, difficult mobility activities and peak expiratory flow. Model 3 adjusted the following variables: sex, age, region, urban/rural, education levels, married status, education levels, body mass index, smoking, alcohol, night sleep duration, napping, difficult mobility activities, peak expiratory flow, accident, fallen down, hip fracture, depression, hypertension, dyslipidaemia, hyperglycaemia, cancer, chronic lung diseases, liver diseases, heart diseases, stroke, kidney diseases, digestive diseases, emotional or psychiatric problems, memory-related diseases, arthritis or rheumatism, and asthma.

creased prevalence of possible sarcopenia and low muscle strength than clean fuel for heating. We believed that our findings have the greater value for public health in the circumstances of accelerating population ageing. This study suggested that indoor air pollution may be a potentially independent risk factor of sarcopenia. Our results provided evidence of evidence-based medicine to support a national strategy for transforming solid fuel into clean fuel, which can reduce the adverse effects of air pollution on public health and decrease ageing-related disease burden in China and worldwide.

As mentioned above, we retrieved two cross-sectional studies analysing the relationships between air pollution exposure with muscle mass and strength.[14,15] One of these for 530 elder aged ≥65 years old, conducted in Taipei, found that an interquartile increase in PM2.5 (1.41 μm/m^3) is associated with 0.4 kg (95% CI: −0.31, −0.58) decrease in muscle mass after 1 year exposure to outdoor air pollution. Handgrip strength had no significant correlation with each ambient air pollution exposure, including PM2.5, sulphur dioxide, ozone, carbon monoxide, and nitrogen dioxide.[14] This study did not assess the effects of indoor air pollution on muscle and sarcopenia. However, the other study involving 31 209 adults suggested that each 10 μg/m^3 increase in PM2.5 may bring a 0.7 kg decrease (95% CI: −1.26, −0.14) of handgrip strength,[15] unlike previous study.[14] The authors also found that solid fuel for cooking is accompanied by the significant reduction of handgrip strength (β = −1.25, 95% CI: −1.74, −0.75) than clean fuel.[15] Regrettably, the study from Lin et al. did not assess the effect of solid fuel for cooking on muscle mass; meanwhile, the correlations between solid fuel for heating with muscle strength and mass were not determined. Overall, limited evidence was available in the relationships between muscle and indoor air pollution, especially in solid fuel for heating. Compared with two previous studies, we provided more detailed evidence about the effects of indoor air pollution on muscle strength and mass. In line with the study of Lin et al., Chinese older population using solid fuel for cooking suffered from a significant decrease (β = −0.424, 95% CI: −0.767, −0.082) of handgrip strength than those with clean fuel use for cooking. One new evidence was that solid fuel for heating also shows a 0.637 kg (95% CI: −1.033, −0.241) lower handgrip strength than clean fuel use for heating. Another new evidence was that solid fuel for cooking has a strongly negative association with muscle mass (β = −0.034, 95% CI: −0.051, −0.019) than clean fuel for cooking. Interestingly enough, solid fuel for cooking was more prone to affect muscle mass, while solid fuel for heating tended more to influence muscle strength. Indoor air pollution caused by solid fuel for heating mainly occurred in winter, which has a continuous effect on individuals' health almost all time of day. Solid fuel for heating always occurred throughout the year, but individuals had short-term exposure to indoor air pollution. Whether and why various patterns of indoor air pollution exposure have the different effects on muscle strength and mass remain to further explore. Additionally, we also found the combined adverse effects of solid fuel for cooking and heating on muscle strength. Referring to ASWG 2019,[4] the conceptions of low muscle strength and mass were applied to our study. Solid fuel for cooking harboured a higher prevalence of low muscle strength and mass than clean fuel for cooking, while solid fuel for heating had the significantly increased risk of low muscle strength but not low muscle mass than clean fuel for heating. We still observed the combined effects of solid fuel for both cooking and heating on the prevalence of low muscle strength and mass.

To our best knowledge, there was lack of literature regarding clinical epidemiological investigation about the associations between sarcopenia with outdoor and indoor air pollution. As an important component of age-related diseases, sarcopenia deserves to deeply explore the correlation with air pollution. This study provided a novel finding that solid fuel for cooking and heating may be a detrimental factor of sarcopenia. In addition, the separate and joint uses of solid fuel for cooking and heating suffered from the higher prevalence of possible sarcopenia compared with the reference group. Even significantly dose-dependent manner was shown in the prevalence of possible sarcopenia with the amount of solid fuel for cooking and heating. The prevalence of severe sarcopenia seemed to be significantly unacted on indoor air pollution. As our results have showed, indoor air pollution not only had the decreased values of handgrip strength and muscle mass but also suffered from the rising prevalence of low muscle strength and muscle mass. In this sense, the observed associations about indoor air pollution and sarcopenia were biologically plausible. The diagnosis of sarcopenia needs to simultaneously assess muscle mass plus muscle strength/physical performance, whereas possible sarcopenia mainly involved the assessment of muscle strength/physical performance.[4] When muscle mass needs to be considered, solid fuel for cooking was likely to have the greater impact on the prevalence of sarcopenia and severe sarcopenia than solid fuel for heating. The prevalence of possible sarcopenia without the assessment of muscle mass showed the opposite effect. Various patterns of indoor air pollution exposure still seemed to have the different influence although we added assessment of physical performance.

At present, the underlying mechanisms linking the relationships between indoor air pollution with muscle and sarcopenia remain unclear. The potential pathophysiology of muscle damage and sarcopenia might include the following mechanisms: inflammation, oxidative stress, microvascular changes, changes in hormones and growth factors, neural plaque changes and motor neuron loss, imbalance in protein metabolism, apoptosis, inactivity, mitochondrial dysfunction, and satellite cell dysfunction.[3] Previous studies demonstrated that pollutants secondary to cigarette smoking can lead to skeletal muscle impairment by inducing muscle protein breakdown and muscle dysfunction,[25,26] declining muscle protein synthesis,[27] and compromising muscle regenerative capacity.[28] Inflammation and oxidative stress caused by air pollution can impair neurotransmitter and neurotrophin signalling, neuronal remodelling, and neurodegeneration.[29] In vivo experiments with rats exposed to air pollution demonstrated that benzo[a]pyrene can stimulate the increase of oxidative stress production, inflammatory cytokines, and proteins mediating apoptotic cell death.[30] Then, these increased expressions can exert deleterious effects on the muscle and result in conditions indicative of sarcopenia. Sarcopenia model further validated the association between benzo[a]pyrene and sarcopenia and confirmed the effect of benzo[a]pyrene in muscle ageing.[30] A large sample epidemiological survey suggested that long-term air pollution exposure has the significantly adverse effect on microvascular health among the general UK population.[31] In addition, solid fuel for cooking was found to accompany by the reduction of self-reported and performance-based physical function among middle-aged and elder Chinese populations.[11] Multiple co-morbidities were frequent underlying causes of sarcopenia, which included depression, neurological disorders, and bone and joint diseases.[3] The majority of these co-morbidities also were caused by air pollution.[9-13,32] Taken together, air pollution has the ability to affect muscle and sarcopenia via different pathways and co-morbidities.

The main strength is that we more comprehensively assess the effects of indoor air pollution on muscle strength and mass in Chinese older population and provide an essential finding about indoor air pollution and age-related sarcopenia by using a high-quality nationwide representative study. Nevertheless, several limitations occur in our study. Firstly, muscle mass was estimated by an anthropometric equation rather than DXA or bioelectrical impedance analysis. However, previous studies have validated the reliability of this estimation formulas in Chinese population[22] and found that the use of anthropometric equation has a cost-effective alternative to DXA/bioelectrical impedance analysis to improve the diagnosis of sarcopenia, meanwhile decrease the risk of radiation exposure secondary to DXA and high cost of measurements.[19] Secondly, solid fuel use was based on a self-report questionnaire rather than the direct measurement of external or internal exposure dose, which potentially influenced the study results. Thirdly, although we have adjusted many potential confounders based on previous references,[20–22] some extra confounders were not included in our study, such as housing conditions and dietary intake. Fourthly, some types of selection bias, such as potential volunteer bias and non-response bias, should also be considered when interpreting and extrapolating our results. Finally, it should be highlighted that the cross-sectional nature of this study restricts us to determine causal associations between solid fuel for cooking and heating with muscle and sarcopenia.

Conclusions

This study provides an essential evidence that indoor air pollution for cooking and heating may be an independent risk factor of muscle impairment and sarcopenia. Our findings support that clean fuel for cooking and heating may facilitate successful ageing and reduce the burden of sarcopenia in older population. Additionally, longitudinal studies are warranted to overcome our study limitation and further validate the associations between indoor air pollution with muscle and sarcopenia.

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Conflict of interest

No relationships or activities that could appear to have influenced the submitted work.

Online supplementary material

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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