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Association between pulmonary ventilation function and cognitive function among middle-aged and older adults: an observational study from Southwest China

Xu Li¹, Lin Li¹, Shuming Ji¹, Anjiao Peng² and Lei Chen^{2*}

Abstract

Background Despite the significant prevalence of chronic obstructive pulmonary disease (COPD) in Southwest China, cognitive function among middle-aged and elderly individuals in this area surpasses the national average. This study aims to reveal the overall pulmonary ventilation function status of this population, and investigate whether pulmonary ventilation dysfunction is a risk factor for mild cognitive impairment (MCI) in this region, as suggested by previous researches.

Methods Data were obtained from the 2019–2021 baseline survey of a natural population cohort study conducted in Southwest China. Pulmonary function was tested by experienced and well-trained medical personnel using a spirometer. The Mini-Mental State Examination was used to evaluate cognitive function. Subsequently, multiple logistic regression analysis was employed to examine the associations between pulmonary function and cognitive levels.

Results A total of 2,337 middle-aged and elderly adults were included in this study, with 10.18% (238 individuals) classified as having mild cognitive impairment. According to the Chinese experts' consensus on the standardization of adult lung function diagnosis, approximately 41.16% (962/2,337) of middle-aged and elderly individuals in Southwest China suffer from pulmonary ventilation dysfunction, predominantly mild (37.53%, 877/2,337), with the primary type being obstructive ventilation dysfunction (38.60%, 902/2,337; COPD: 14.21%, 332 participants). And 81.56% participants (1,906/2,337) were found to have small airway dysfunction. Multiple logistic regression analyses showed that individuals with poor pulmonary ventilation function (PPF) were associated with an increased risk of MCI (OR [95% CI]: 1.38 [1.04, 1.83], $P=0.026$). Moreover, the more severe the pulmonary ventilation dysfunction, the higher the risk of cognitive impairment (P for trend = 0.009). Similar association were found between PPF and MCI when we use ATS/ERS technical standards. No significant association was observed between small airway dysfunction and cognitive impairment (OR [95% CI]: 1.05 [0.72, 1.56], $P=0.819$).

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Conclusions The pulmonary function status of middle-aged and elderly individuals in Southwest China requires attention, particularly regarding obstructive pulmonary ventilation dysfunction. We recommend integrating pulmonary health assessments into routine care for these populations to raise awareness of lung health, improve lung function, and ultimately enhance cognitive function.

Keywords Pulmonary ventilation function, Lung function, Cognitive function, Mild cognitive impairment

Background

With the intensifying trend of population aging [1], elderly health issues have garnered widespread attention. Among these, cognitive function problems, such as mild cognitive impairment (MCI) and dementia, have been regarded as a global health priority for the elderly by the WHO [2]. According to the WHO's 2019 report on the leading causes of global deaths, dementia ranked seventh [3]. And it is projected that the number of dementia patients worldwide will increase from 54.7 million in 2019 to 152.8 million by 2050 [4]. The progression of dementia can be divided into three stages: the preclinical phase, mild cognitive impairment, and the dementia stage [5, 6]. Due to the lack of effective treatments [3], once patients enter the dementia stage, the disease course becomes irreversible. Therefore, the reversible MCI stage is a critical juncture for intervention and prevention of dementia. Identifying modifiable risk factors during the MCI stage may be one of the most effective strategies to delay the onset of dementia.

Previous epidemiological studies have shown that poor lung function is associated with cognitive decline and an increased risk of dementia [7–12]. Impaired lung function may affect cognitive function through mechanisms such as mediating chronic hypoxemia, systemic inflammation, oxidative stress, cerebral arteriosclerosis, and vascular injury [13]. However, some inconsistent findings remain [14, 15]. To date, evidence from mainland China is relatively limited [16, 17]. Furthermore, most studies have focused on dementia as the outcome measure, with limited attention to the reversible stage of mild cognitive impairment (MCI) [8, 10, 15]. Additionally, the evaluation of lung function in these studies has often centered on chronic obstructive pulmonary disease (COPD) [10, 18] or some lung function indicators [7, 11], with few comprehensive assessments of pulmonary ventilation function [8]. Therefore, it is essential to explore the association between the overall pulmonary ventilation function and MCI in mainland China.

Pulmonary function tests are considered the gold standard for diagnosing pulmonary ventilation dysfunction. However, reports indicated that the rate of pulmonary function testing among Chinese residents aged 40 and above was only 6.7% in 2019–2020 [19]. Consequently, the awareness rate of pulmonary function impairment among middle-aged and elderly individuals in China is generally low, with only 0.9% for COPD [20]. Due to

differences in environment and lifestyle [21, 22], pulmonary function levels seems to vary among populations in different regions of China. For instance, in the case of chronic obstructive pulmonary disease (COPD), data from the Chinese Center for Disease Control and Prevention in 2018 indicated that the prevalence of COPD among individuals aged 40 and above is highest in the Southwest region at 20.2%, and lowest in the Central region at 10.2% [20]. To the best of our knowledge, no studies have reported in detail the real-world status of pulmonary ventilation function, such as the proportion, types, and severity of pulmonary ventilation dysfunctions, among middle-aged and elderly individuals over 45 years old in Southwest China.

Sichuan Province, located in Southwest China, has been reported to have a relatively superior cognitive function status among its population compared to the national average, with the prevalence of dementia in adults aged 60 years or older being approximately 4.74% (average: 6.0%) [23]. However, the prevalence of COPD, one of the most common type of pulmonary ventilation dysfunction, in this region, seems to be higher than the national average (Sichuan 16.11% vs. average 8.60%) [24, 25]. We are curious whether pulmonary ventilation dysfunction in this region remains a potential risk factor for cognitive impairment, as suggested by previous studies. Therefore, based on the natural population cohort established by West China Hospital of Sichuan University, this study aimed to comprehensively reveal the characteristics of pulmonary ventilation function status in people over 45 years old in this region and its association with cognitive function from the aspects of the type and severity of pulmonary ventilation dysfunction. The findings may help identify modifiable risk factors for cognitive decline and provide a theoretical basis for the prevention and control of cognitive impairment.

Methods

Study design and data sources

We conducted a cross-sectional study, and the data were obtained from the baseline survey of the Natural Population Cohort Study of West China Hospital, Sichuan University (No.ChiCTR1900024623) [26]. Residents over the age of 20 from communities in Sichuan Province were invited to voluntarily participate in this cohort study. Baseline data were gathered through structured questionnaires, biological sample collections, and physical/

clinical examinations. So far, the cohort has completed its baseline survey in the cities of Chengdu, Mianzhu, and Ganzi between 2019 and 2021.

This study included baseline participants who have completed the assessment of cognitive function and lung function. Individuals who lacked information on some key covariates (such as smoking status, and history of neurological or respiratory diseases) were excluded. The study was approved by the ethical community of West China Hospital, Sichuan University, and all participants signed informed consent forms.

Measurement of pulmonary function

Pulmonary function was tested using a spirometer (Jaeger-MasterScreen Pneumo, Germany). Participants who screened positive for major contraindications to spirometry, such as myocardial infarction, stroke or shock in the past three months, were excluded. The examination was conducted in a relatively quiet, well-ventilated environment with stable temperature and humidity. The procedure was carried out by medical personnel with relevant operational experience who had passed the necessary assessments. Each participant's test was repeated at least three times, and the results meeting quality control standards were used as the final pulmonary function parameter values. Through this examination, we obtained the following parameters: FVC (Forced Vital Capacity), FEV1 (Forced Expiratory Volume in one second), FEV1/FVC, MMEF_{25-75%} (Maximal Mid-Expiratory Flow between 75% and 25% of the FVC), MEF_{50%} (Maximal Expiratory Flow at 50% of the FVC), and MEF_{25%} (Maximal Expiratory Flow at 25% of the FVC).

According to the Chinese experts' consensus on the standardization of adult lung function diagnosis [27], we defined participants' pulmonary ventilation function as follows: (1) Obstructive ventilatory dysfunction: FEV1/FVC% pred < 92%. (2) Restrictive ventilatory dysfunction: FVC% pred < 80%. (3) Mixed ventilatory dysfunction: Both of the above criteria are met simultaneously. (4) Normal pulmonary ventilation function: None of the above criteria are met. Furthermore, we classified individuals with any ventilatory dysfunction as having poor pulmonary function (PPF), while the others were classified as having normal pulmonary function (NPF). Additionally, according to commonly used standards by clinicians in China, we graded the severity of lung function impairment in the PPF group based on FEV1% pred: mild impairment for FEV1% pred ≥ 70% and moderate-to-severe impairment for FEV1% pred < 70% [28]. To assess small airway dysfunction, we utilized MMEF_{25-75%}, MEF_{50%}, and MEF_{25%}. A diagnosis of small airway dysfunction was made when at least two of these three indicators were less than 65% of predicted values [29]. In addition, we assessed COPD based on the Global

Initiative for Chronic Obstructive Lung Disease (GOLD) criteria [30]: (1) Non-COPD: FEV1/FVC ≥ 0.7; (2) COPD: FEV1/FVC < 0.7.

To facilitate sensitivity analyses, we reclassified pulmonary ventilation function according to ATS/ERS technical standards [31]: (1) Obstructive ventilatory dysfunction: FEV1/FVC < LLN (the lower limit of normal). (2) Restrictive ventilatory dysfunction: FVC < LLN. (3) Mixed ventilatory dysfunction: Both criteria are met simultaneously. (4) Normal pulmonary ventilation function: absence of restrictive or obstructive impairment. The LLN values were calculated using the formula applicable to the Chinese population, incorporating age, sex, and height [32]. The severity of ventilatory dysfunction was graded using Z-scores [31].

Assessment of cognitive function

We used the Mini-Mental State Examination (MMSE) to evaluate the cognitive function of participants [33]. This scale has good reliability and validity [34] and is completed under the guidance of two professionals in a quiet environment, using unified terminology. The total score of MMSE ranges from 0 to 30, and a higher score indicates better cognitive function. In this study, an MMSE score of less than 24 was defined as MCI [35].

Measurement of covariates

Structured questionnaire [26] was used to collect information of covariates including age, gender, occupation, marital status, education level, drinking status, smoking status, leisure-time physical activity (LTPA), live alone, eat alone, status of depression, anxiety, and history of diabetes, hypertension, cancer, dyslipidemia, nervous system disease, and respiratory disease. Besides, fasting blood was collected for biochemical detection to evaluate the health status, such as dyslipidemia and diabetes. Objective measurements were used to assess the status of body mass index (BMI) and hypertension. To identify hypertension, diabetes, or dyslipidemia, either a positive self-report by the participant or a positive clinical test result was sufficient. Overweight was defined as a BMI ≥ 24.

Statistical analysis

Data were expressed as frequency (percentage) and median (interquartile range, IQR) for baseline characteristics. Nonparametric tests for continuous variables and chi-square tests for categorical variables were performed to compare the differences in baseline characteristics across different pulmonary function groups. Multiple logistic regression models were used to test the relationship between pulmonary function and cognitive function, and the variables with a *p*-value < 0.1 in univariate analysis were selected as potential confounding variables

in the model. Further subgroup analyses were conducted according to age, gender, smoking status, drinking status, LTPA level, and history of pulmonary diseases. Additionally, we reassessed the level of pulmonary ventilation function according to ATS/ERS standards and conducted sensitivity analyses to explore the robustness of the association between pulmonary ventilation function and cognitive function. All analyses were performed using R 4.1.2 software, and 2-sided *p*-values < 0.05 were considered statistically significant.

Results

Participant characteristics

A total of 2,337 subjects were included in the analyses. Among them, 238 individuals (10.18%) were classified as having mild cognitive impairment. Based on the classification standards for pulmonary ventilation function outlined in the Chinese expert consensus, 41.16% (962 participants) were classified as having poor pulmonary function (PPF). The breakdown of PPF was as follows: 38.60% (902 participants) were identified with obstructive ventilatory dysfunction (COPD: 14.21%, 332 participants), 0.73% (17 participants) had restrictive ventilatory dysfunction, and 1.84% (43 participants) had mixed ventilatory dysfunction (Fig. 1). Regarding the severity of lung function impairment, 37.53% (877 participants) had mild PPF, and 3.64% (85 participants) had

moderate-to-severe PPF. Additionally, a high proportion of participants, 81.56% (1,906 participants), were found to have small airway dysfunction. Based on the ATS/ERS technical standards for pulmonary function classification, the ventilatory function status of the enrolled population is shown in Supplementary Fig. 1.

The median ages were both 59 years for participants with normal and poor pulmonary function (Table 1). Participants with PPF status seemed to have higher proportion of MCI (12.37% VS 8.65%). In addition, there were significant differences in gender, education level, BMI, and history of respiratory disease between the participants with NPF and PPF status (*P* < 0.05).

Association between pulmonary ventilation function and mild cognitive impairment among middle-aged and older adults in Southwest China

Multiple logistic regression analyses showed that individuals with poor pulmonary ventilation function were associated with an increased risk of MCI (OR [95% CI]: 1.38 [1.04, 1.83], *P* = 0.026, Table 2). Furthermore, higher severity of lung dysfunction seemed to be associated with a higher risk of MCI (OR [95% CI] for mild impairment: 1.33 [0.99, 1.79], *P* = 0.061; OR [95% CI] for moderate to severe impairment: 2.10 [1.07, 3.96], *P* = 0.026; *P* for trend = 0.009). Regarding the types of ventilatory dysfunction, we found that individuals with obstructive

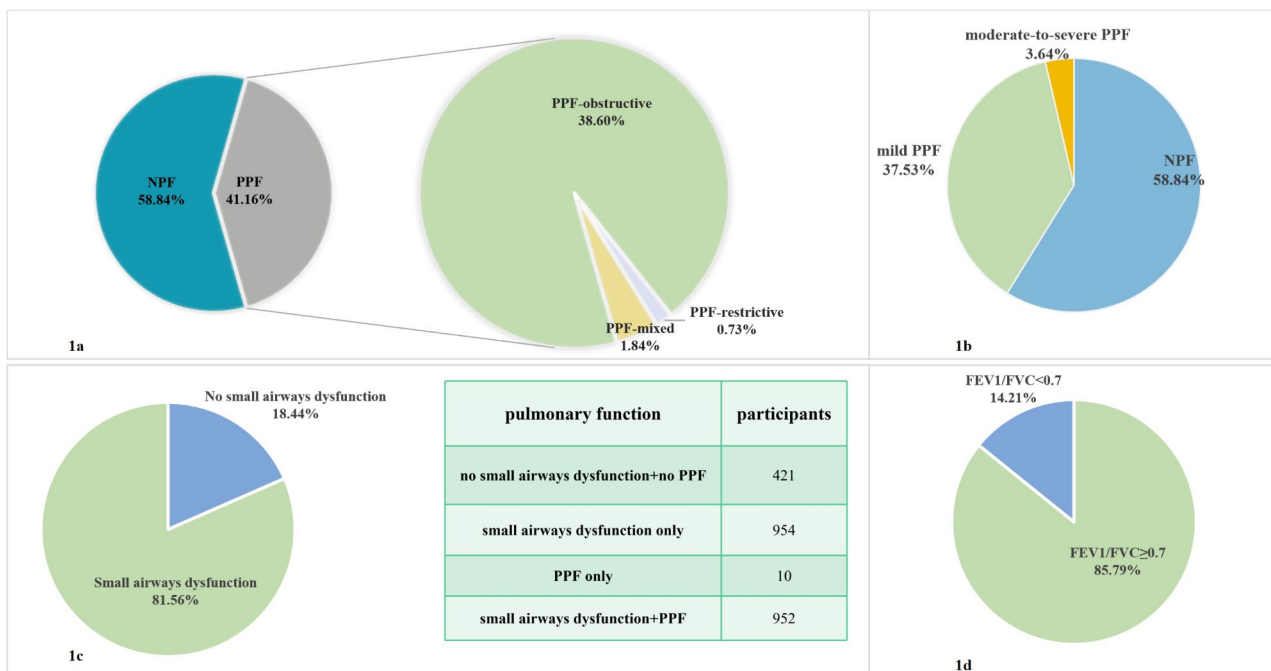


Fig. 1 Characteristics of pulmonary ventilation function of the study participants (classified according to Chinese expert consensus). **a.** Distribution of pulmonary function status in study participants. **b.** Severity distribution of pulmonary function impairment. **c.** Distribution of small airway dysfunction prevalence. **d.** Distribution of COPD (FEV1/FVC < 0.7) status. NPF, normal pulmonary function; PPF, poor pulmonary function; PPF-obstructive, obstructive ventilatory dysfunction; PPF-restrictive, restrictive ventilatory dysfunction; PPF-mixed, mixed ventilatory dysfunction

Table 1 Characteristics of study participants

Variables	NPF(n = 1375)	PPF(n = 962)	Z/ χ^2	P
Age (years), median [q1, q3]	59 [54, 65]	59 [54, 66]	-0.83	0.404
Gender, n (%)			4.80	0.028
Male	447 (32.51)	271 (28.17)		
Female	928 (67.49)	691 (71.83)		
Education, n (%)			13.55	0.004
Primary school and below	447 (32.51)	363 (37.73)		
Middle school	578 (42.04)	379 (39.40)		
High school or vocational high school	253 (18.40)	180 (18.71)		
College and above	97 (7.05)	40 (4.16)		
Marital status, n (%)			0.06	0.812
Unmarried/divorced	131 (9.53)	88 (9.15)		
Married/cohabitation	1244 (90.47)	874 (90.85)		
Occupation, n (%)			2.05	0.152
None	1052 (76.51)	761 (79.11)		
In work	323 (23.49)	201 (20.89)		
Smoking, n (%)			1.87	0.393
Never	1152 (83.78)	786 (81.70)		
Ever	103 (7.49)	78 (8.11)		
Current	120 (8.73)	98 (10.19)		
Passive smoking, n (%)*			0.83	0.363
No	959 (74.11)	681 (75.92)		
Yes	335 (25.89)	216 (24.08)		
Drinking, n (%)			2.27	0.321
Never	964 (70.11)	702 (72.97)		
Ever	202 (14.69)	127 (13.20)		
Current	209 (15.20)	133 (13.83)		
Live alone, n (%)			0.44	0.509
No	1274 (92.65)	899 (93.45)		
Yes	101 (7.35)	63 (6.55)		
Eat alone, n (%)			0.05	0.821
No	1250 (90.91)	878 (91.27)		
Yes	125 (9.09)	84 (8.73)		
Physical activity, n (%)			2.32	0.128
< 11.25 MET-hours/week	453 (32.95)	347 (36.07)		
\geq 11.25 MET-hours/week	922 (67.05)	615 (63.93)		
Body mass index, n (%)			12.88	<0.001
< 24 kg/m ²	583 (42.40)	481 (50.00)		
\geq 24 kg/m ²	792 (57.60)	481 (50.00)		
Depression, n (%)			0.40	0.528
No	1299 (94.47)	902 (93.76)		
Yes	76 (5.53)	60 (6.24)		
Anxiety, n (%)			0.15	0.697
No	1293 (94.04)	900 (93.56)		
Yes	82 (5.96)	62 (6.44)		
Diabetes, n (%)			2.13	0.144
No	1210 (88.00)	866 (90.02)		
Yes	165 (12.00)	96 (9.98)		
Hypertension, n (%)			1.05	0.306
No	803 (58.40)	583 (60.60)		
Yes	572 (41.60)	379 (39.40)		
Dyslipidemia, n (%)			3.79	0.052
No	418 (30.40)	330 (34.30)		
Yes	957 (69.60)	632 (65.70)		

Table 1 (continued)

Variables	NPF(n=1375)	PPF(n=962)	Z/ χ^2	P
Cancer, n (%)			1.01	0.314
No	1351 (98.25)	951 (98.86)		
Yes	24 (1.75)	11 (1.14)		
Nervous system disease, n (%)			0.03	0.869
No	1251 (90.98)	878 (91.27)		
Yes	124 (9.02)	84 (8.73)		
Respiratory disease, n (%)			16.09	<0.001
No	1252 (91.05)	824 (85.65)		
Yes	123 (8.95)	138 (14.35)		
MCI, n (%)			8.14	0.004
No	1256 (91.35)	843 (87.63)		
Yes	119 (8.65)	119 (12.37)		

Notes: MCI, mild cognitive impairment; NPF, normal pulmonary function; PPF, poor pulmonary function

*only 2191 participants reported passive smoking status

pulmonary ventilation dysfunction had a higher risk of MCI compared to those without ventilatory dysfunction (OR [95% CI]: 1.35 [1.01, 1.79], $P=0.040$). Similar results were found in individuals with COPD (OR [95% CI]: 1.60 [1.09, 2.32], $P=0.014$). However, no significant association was observed in individuals with restrictive ventilatory dysfunction (OR [95% CI]: 1.76 [0.80, 3.54], $P=0.135$). Additionally, no significant association was found between small airway dysfunction and MCI (OR [95% CI]: 1.05 [0.72, 1.56], $P=0.819$).

Results from sensitivity analysis indicated that when applying the ATS/ERS technical standards for pulmonary function assessment, ventilatory dysfunction remained positively associated with MCI (OR [95% CI]: 1.47 [1.04, 2.07], $P=0.029$, Supplementary Table 2). This association was primarily evident in individuals with obstructive ventilatory dysfunction (OR [95% CI]: 1.54 [1.04, 2.55], $P=0.027$). Moreover, a greater severity of obstruction was linked to an increased risk of MCI (OR [95% CI] for mild impairment: 1.34 [0.81, 2.16], $P=0.235$; OR [95% CI] for moderate to severe impairment: 1.87 [1.08, 3.18], $P=0.023$; P for trend=0.014).

Subgroup analysis

Although there was no statistically significant difference in the correlation between pulmonary function levels and the risk of MCI when stratified by age, gender, smoking status, drinking status, LTPA level or history of respiratory disease (all P for interaction > 0.05), the association seemed to be more obvious in males, ever/current smoker, those with an LTPA level < 11.25 MET-hours/week, and those with a history of respiratory disease (Fig. 2).

Discussion

This study is the first to assess the overall pulmonary ventilation function status and its association with cognitive function among middle-aged and elderly populations in Southwest China under real-world conditions. We found that the lung function health of individuals aged 45 and above in this region should not be overlooked, and that pulmonary ventilation dysfunction is associated with a higher risk of mild cognitive impairment.

Overall status of pulmonary ventilation dysfunction in Southwest China

Based on Chinese experts' consensus on the standardization of adult lung function diagnosis, our study revealed that approximately 41.16% (962/2337) of middle-aged and elderly individuals in Southwest China suffer from pulmonary ventilation dysfunction, predominantly mild (91.16%, 877/962), with the primary type being obstructive ventilation dysfunction (93.76%, 902/962). Previous research also indicates that the prevalence of obstructive ventilation dysfunction is higher than that of restrictive dysfunction [8, 36]. Obstructive pulmonary ventilation dysfunction refers to the obstruction of airflow in the bronchi and bronchioles, encompassing diseases such as chronic obstructive pulmonary disease (COPD), asthma, bronchiectasis, and cystic fibrosis [37]. Among these, COPD contributes the most significant disease burden [25, 38], yet the awareness rate among patients is less than 2% [24]. Research has highlighted that by the time asymptomatic and unaware COPD patients experience symptoms such as shortness of breath, their lung function may already be impaired by more than 50%, suggesting a missed opportunity for optimal intervention [39]. Therefore, it is imperative to implement measures to improve the level of pulmonary function testing among residents aged 40 and above, especially high-risk groups

Table 2 The association between pulmonary ventilation function and mild cognitive impairment

Pulmonary Function	No. of controls/cases (n = 2099/238)	OR (95%CI)	P
Pulmonary ventilation function ¹			
NPF	1256/119	1.00	
PPF	843/119	1.38 (1.04, 1.83)	0.026
Pulmonary ventilation function ²			
Normal	1256/119	1.00	
Mild impairment	774/103	1.33 (0.99, 1.79)	0.061
Moderate to severe impairment	69/16	2.10 (1.07, 3.96)	0.026
Obstructive pulmonary ventilation dysfunction ³			
No	1270/122	1.00	
Yes	829/116	1.35 (1.01, 1.79)	0.040
COPD ⁴			
No	1823/182	1.00	
Yes	276/56	1.60 (1.09, 2.32)	0.014
Restrictive pulmonary ventilation dysfunction ⁵			
No	2049/228	1.00	
Yes	50/10	1.76 (0.80, 3.54)	0.135
Small airways dysfunction ⁶			
No	394/37	1.00	
Yes	1705/201	1.05 (0.72, 1.56)	0.819

Model 1: adjusted for gender, education level, BMI, and history of respiratory disease and dyslipidemia. Model 2: adjusted for gender, age, education level, BMI, smoking, anxiety, and history of respiratory disease and dyslipidemia. Model 3: adjusted for gender, education level, BMI and history of respiratory disease and dyslipidemia. Model 4: adjusted for gender, age, education level, smoking, drinking, and history of hypertension, diabetes, respiratory disease and dyslipidemia. Model 5: adjusted for gender, age, smoking, and history of respiratory disease and hypertension. Model 6: adjusted for gender, education level, and history of respiratory disease and dyslipidemia. NPF, normal pulmonary function; PPF, poor pulmonary function

for chronic respiratory diseases, to increase their awareness of lung function status.

Relationship between pulmonary ventilation dysfunction and MCI

Despite middle-aged and elderly individuals in this region exhibiting relatively poor lung function but relatively good cognitive function compared to the national average, our study still found that impaired pulmonary ventilation may be a potential risk factor for MCI. Following sensitivity analysis using the ATS/ERS standards, ventilatory dysfunction remained positively associated with MCI, reinforcing the robustness of this relationship. The

study suggests that hypoxia resulting from ventilatory impairment may impact the activity of oxygen-dependent enzymes crucial for synthesizing neurotransmitters such as acetylcholine, potentially leading to neuronal dysfunction [40]. Additionally, systemic inflammation associated with ventilatory dysfunction may damage the central nervous system via the cyclooxygenase pathway, with sustained inflammatory responses accelerating neurodegenerative changes and impairing cognitive function [41–43]. Previous research has reported that individuals with impaired lung function could exhibit greater overall and frontal-parietal grey matter loss, as well as higher volumes of white matter hyperintensities [8], thus contributing to cognitive decline [44–46]. Although previous studies have suggested that the association between lung function and cognitive function may be partly due to shared risk factors [47], such as older age, lower educational level, smoking, and lack of physical activity [22, 25, 48], our study found that even after controlling for these confounding factors, the association remained significant. This suggests a potentially independent relationship between poor lung function and cognitive decline. Furthermore, a study found that COPD patients have a significantly greater proportion of individuals with motoric cognitive risk (MCR) syndrome compared to healthy subjects and asthmatics, indicating possible interconnections between the brain and pulmonary system and skeletal muscle [49].

Unlike other regions, Sichuan province in Southwest China is known for its leisure culture and slow-paced lifestyle [50]. Sichuan residents, particularly the elderly who have more free time, enjoy gathering for tea and playing mahjong [50]. Simultaneously, they place a strong emphasis on physical activity, often going for evening walks or engaging in square dancing with friends or partners, resulting in higher physical activity levels than the national average [51]. This lifestyle, characterized by an emphasis on both physical exercise and social interaction, is beneficial for cognitive function [51, 52]. It may help us understand why, despite having poorer lung function, the cognitive levels of the middle-aged and elderly in this region are higher than the national average. Based on these findings, we recommend that middle-aged and elderly individuals prioritize lung health and actively engage in physical activities and social interactions to enhance their cognitive function. Additionally, considering the detrimental effects of air pollution and smoking on lung and cognitive function [16, 53], we urge policymakers to take proactive measures to control air pollution and improve air quality, as well as to implement community-based pulmonary rehabilitation programs and smoking cessation support to enhance residents' lung health.

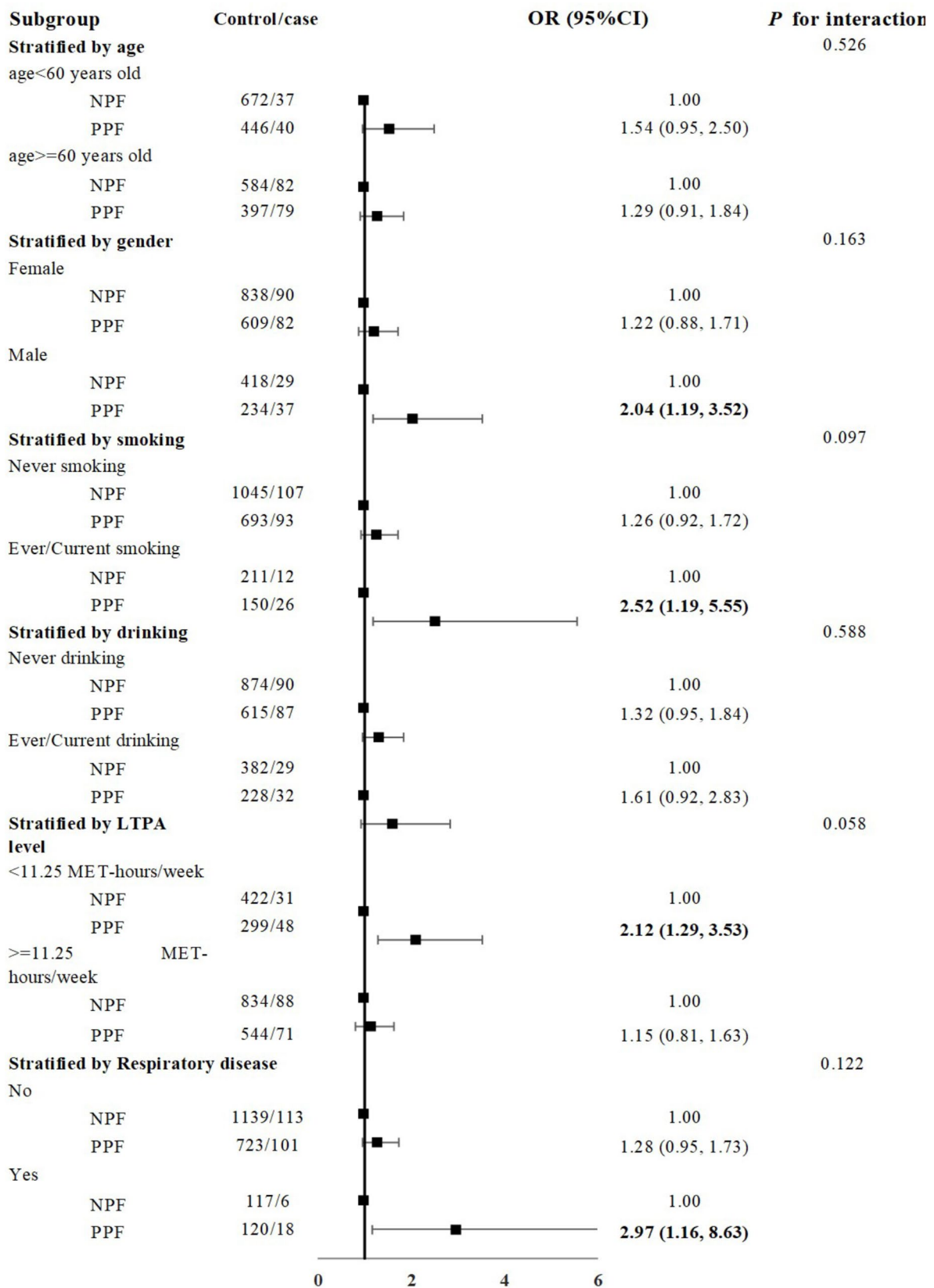


Fig. 2 Subgroup analysis. All models were adjusted for education level, BMI, history of dyslipidemia, and (where appropriate) gender, and history of respiratory diseases. NPF, normal pulmonary function; PPF, poor pulmonary function

Our further analysis found that the positive association between PPF and MCI was only observed in the obstructive PPF group and not in the restrictive PPF group, while previous researches have shown that both restrictive and obstructive pulmonary ventilation dysfunctions are associated with an increased risk of cognitive impairment [8, 36]. The discrepancy in our study might be attributed to the sample size and the lower detection rate of restrictive PPF in our participants.

Small airway dysfunction and its relationship with MCI

Our study also found that the prevalence of small airway dysfunction among middle-aged and elderly individuals in Southwest China is as high as 81.56%. A national cross-sectional study similarly reported that the prevalence of small airway dysfunction among Chinese individuals aged 45 and above ranges from approximately 50–80%, with an increasing prevalence with advancing age [54]. However, our study did not find an association between small airway dysfunction and cognitive impairment. This may be because small airway dysfunction is considered a precursor to COPD and asthma [54]. Initially, the obstruction in these airways leads to minimal measurable changes in airway resistance. It is only in the later stages of the disease that small airway obstruction may disproportionately harm lung function [55]. For our study participants with small airway dysfunction (1906 participants), 50.05% (954/1906) had isolated small airway dysfunction, while approximately 49.95% (952/1906) had concomitant pulmonary ventilation dysfunction, the vast majority of which was mild and in the early stages of the disease. Therefore, the impact of small airway dysfunction on lung ventilation function and blood oxygen levels may not have been evident, explaining the lack of a significant association with cognitive impairment. Nonetheless, as a precursor symptom, small airway dysfunction can provide an important early warning for potential lung function impairment.

Findings from subgroup analysis

Previous studies have shown that individuals who smoke or have a history of respiratory diseases are more likely to experience impaired lung function [25]. Additionally, males, due to higher smoking rates and higher likelihood of occupational exposures to dust, are at a greater risk for compromised lung function. Therefore, the association between lung function and cognitive function may be more detectable in these groups. It is known that moderate physical activity is a protective factor for cognitive function [22]. Our study showed a significant association between pulmonary ventilation dysfunction and cognitive impairment among those lacking physical activity, whereas this association was not statistically significant in individuals actively engaging in physical activity. These

findings suggest that for middle-aged and elderly individuals with impaired lung function, encouraging regular physical exercise, smoking cessation, and minimizing occupational dust exposure could be effective measures to improve lung function and cognitive levels in this population.

Limitations and future research directions

There are several limitations to this study. First, as a cross-sectional study, it does not allow for the inference of causal relationships between lung function decline and cognitive impairment. Second, we primarily utilized pulmonary ventilation function criteria from the Chinese expert consensus, which, while widely employed by clinicians in China for lung function diagnosis, has not been broadly recognized internationally. However, even when applying the ATS/ERS standard for classifying pulmonary ventilation function, the main results remained unchanged, thereby reflecting the robustness of our findings from an alternative perspective. Third, similar to the China Kadoorie Biobank study, our participants did not inhale bronchodilators before undergoing pulmonary function tests, which may affect the accuracy of estimating the detection rate of pulmonary ventilation dysfunction [56]. Fourth, although only three cities in Sichuan Province were surveyed, we took into account regions with different income levels to maximize the representation of participants with limited resources. Despite these limitations, this study revealed the real-world status of pulmonary ventilation function among middle-aged and older people in Southwest China from multiple dimensions and demonstrated the positive association between lung function and cognitive function. Our results will help expand the list of modifiable risk factors for MCI and provide a reference for the development of early warning and prevention strategies for MCI in the future. Additionally, future research could consider enhancing pulmonary measurements, such as employing bronchodilators during lung function tests; measuring carbon monoxide and other pollutants in the blood and investigating their roles in inflammatory damage to airways, blood vessels, immune cells, and neurons.

Conclusions

The lung health status of middle-aged and elderly individuals in Southwest China warrants attention, especially the prevalence of obstructive pulmonary ventilation dysfunction. Poor pulmonary ventilation function is associated with a higher risk of cognitive impairment, and early intervention in lung health may serve as a viable strategy for mitigating cognitive decline. We recommend incorporating pulmonary health assessments into routine care for these populations to enhance awareness of lung

health, improve lung function, and subsequently boost cognitive function.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12890-024-03403-0>.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions

X.L. contributed to the conception, design, analysis, and manuscript preparation. L.L. contributed to the design and data analysis. S.M.J. and A.J.P. contributed to the data collection and manuscript revision. L.C. contributed to the conception and revised the final draft of the manuscript.

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Data availability

The datasets of the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the ethical community of West China Hospital, Sichuan University. We confirmed that all methods were performed in accordance with relevant guidelines and regulations to protect human subjects. All participants read and signed written informed consent forms.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Abbreviations

PPF poor pulmonary function.
NPF normal pulmonary function.
MCI mild cognitive impairment.
COPD chronic obstructive pulmonary disease.
FVC Forced Vital Capacity.
FEV1 Forced Expiratory Volume in one second.
MMEF_{25–75%} Maximal Mid-Expiratory Flow between 75% and 25% of the FVC.
MEF_{50%} Maximal Expiratory Flow at 50% of the FVC.
MEF_{25%} Maximal Expiratory Flow at 25% of the FVC.
MMSE Mini-Mental State Examination.

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