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The association between abdominal obesity and pulmonary function trajectories among patients with COPD

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The association between abdominal obesity and pulmonary function trajectories among patients with COPD remain to be unclear. This study aimed to explore the association between abdominal obesity and pulmonary function trajectories among patients with COPD. Data were collected from the China Health and Retirement Longitudinal Study, which was a nationally representative investigation. The pulmonary function indicator was peak expiratory flow (PEF). Abdominal obesity was assessed using waist circumference, which was categorized into two groups: < 90/85 cm and ≥ 90/85 cm, in men/women. Latent class growth analysis was used to identify distinct pulmonary function trajectories. The logistic regression was used to assess the association between abdominal obesity and pulmonary function trajectories. Finally, a total of 775 patients with COPD aged 45 years and older were included, and 301 participants (38.84%) were abdominal obesity. The mean PEF value showed a decreasing trend, with respective average values of 205.84 L/min (SD = 104.16), 199.99 L/min (SD = 99.52), and 196.06 L/min (SD = 86.74) in 2011, 2013 and 2015. Two PEF trajectories were identified: "above average-high descending" trajectory (*n* = 187, 24.13%) and "low-maintenance" trajectory (*n* = 588, 75.74%). Unadjusted and adjusted analysis showed that baseline higher waist circumference was associated with "low-maintenance" trajectory. A negative association between abdominal obesity and pulmonary function trajectories was observed among patients with COPD. This suggests that increased abdominal fat may accelerate the decline of pulmonary function over time. These findings provide evidence for designing targeted programs to improve pulmonary function, particularly for patients with COPD of abdominal obesity.

Keywords Respiratory function, Peak expiratory flow rate, Chronic lung disease

Chronic obstructive pulmonary disease (COPD) is a common chronic respiratory disease in the elderly, characterized by persistent airflow restriction and pulmonary disorders, which could be recurrent and aggravated rapidly[1]. It is a global public health challenge. In 2019, chronic respiratory diseases (CRDs) ranked as the third leading cause of mortality globally, resulting in an estimated 4.0 million deaths (95% uncertainty interval 3.6–4.3) and exhibiting a global prevalence of 454.6 million cases (417.4–499.1). Notably, COPD, with a prevalent case of 212.3 million individuals (200.4–225.1), emerged as the primary cause of death associated with CRDs, accounting for 3.3 million deaths (falling within a 95% uncertainty interval of 2.9 to 3.6 million)[2]. In China, about 100 million adults over 20 years old suffered from COPD in 2015[3], where it was identified as the third leading cause of death, with 945,000 deaths in 2017[4]. Thus, considerable attention needs to be paid to COPD in China.

Patients with COPD exhibit progressive decline of pulmonary function. Due to the complex and chronic nature of respiratory diseases, there may be significant heterogeneity in pulmonary function changes among patients with respiratory diseases. Moreover, previous research has found that there was heterogeneity in

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pulmonary function of healthy individuals[5]. Therefore, the pulmonary function trajectories of patients with COPD may vary greatly.

Abdominal obesity has been reported to be associated with a high risk of respiratory injury in different populations. Molani et al. found the negative association between abdominal obesity and pulmonary function in healthy adults[6]. Zhang et al. observed that abdominal obesity was associated with the increased risk of airflow obstruction[7]. Furthermore, abdominal obesity clusters were significantly associated with lower forced vital capacity (FVC), FVC percent predicted, and force expiratory volume in 1 s (FEV1) measures than normal weight and low waist circumference cluster in asthma patients[8]. In previous reports, the relationship between abdominal obesity and pulmonary function has been characterized in children and adolescents[9], healthy adults[6] and asthma patients[8]. Although previous cross-sectional studies explored the relationship between abdominal obesity and pulmonary function[7–9], these studies primarily evaluated the variables at a particular time point. Gaining insight regarding the association between abdominal obesity and pulmonary function trajectories among patients with COPD has important implications for current understanding of the burden of decline pulmonary function among the particular individuals, potentially guiding preventative treatments and appropriate interventions.

Peak expiratory flow (PEF), defined as the maximum instantaneous airflow rate attained during a forced expiration maneuver performed at maximal lung inflation, exhibits remarkable simplicity and cost-effectiveness[10,11]. The acquisition of PEF measurements is straightforward and can be readily achieved even by individuals without specialized training, making it a practical tool for large-scale studies involving older adults[10,11]. However, there is limited evidence linking pulmonary function, specifically PEF, with abdominal obesity among patients with COPD. To date, there were multiple studies reporting longitudinal pulmonary function changes and exploring relevant factors associated with the different trajectories, justification of focusing on abdominal obesity and pulmonary function was fair. Therefore, the association between abdominal obesity and pulmonary function trajectories, specially PEF trajectories among patients with COPD remain to be established.

Purpose

This study aimed to explore the association between abdominal obesity and pulmonary function trajectories among patients with COPD, thus providing a reference for programs aimed at improving pulmonary function, in order to develop targeted interventions for patients with COPD of abdominal obesity.

Methods

Participants

Data were collected from the China Health and Retirement Longitudinal Study (CHARLS), which was a national database that consisted of individuals aged 45 years and older. This survey covered 450 village level units of 150 counties and 28 provinces in China[12]. This survey was conducted in 2011 and would be followed up every 2 years using the same biomedical instruments and questionnaires[12]. Eligible survey subjects were selected using a four-stage, stratified, cluster probability sampling strategy[12]. The research assistants who have received training conducted interviews with eligible participants to collect information including demographic data, health-risk behaviors, and anthropometric measurements[12]. Study subjects were asked whether or not a physician had diagnosed them with COPD, with a response of "yes" being used to define participants with COPD[12]. The CHARLS survey data have been released in five waves. However, the wave-4 and wave-5 only released partial data, excluding anthropometric measurements. Therefore, we only utilized data from wave-1 (2011; 17,708 respondents), wave-2 (2013; 18,612 respondents), and wave-3 (2015; 21,095 respondents). Participants were excluded if: (1) they did not have COPD; or (2) they were under 45 years of age; or (3) the data about BMI, waist circumference, and PEF data were missing during two follow-up visits; or (4) more than 50% of the variables to be studied were missing.

Ethical approval

All participants signed an informed consent. The survey has approved by the Institutional Review Board (IRB) at Peking University (IRB approval number: IRB00001052-11015). All methods were performed in accordance with the relevant guidelines and regulations within the manuscript.

Dependent variable

The pulmonary function indicator was peak expiratory flow (PEF), which was assessed using a peak lung flow meter (Shanghai, China). Participants were directed to stand, inhale deeply, securely enclose the mouthpiece with their mouths, and then exhale forcefully and rapidly. This procedure was repeated thrice, with 30-s intervals between each attempt[10]. Three measurements were conducted, and the average was used.

Independent variable

Abdominal obesity was assessed using waist circumference. The waist circumference was measured using a soft measuring tape placed over the clothing around the waist at the level of the navel[12]. At the conclusion of expiration, the navel level was chosen, and the waist circumference was measured[13]. Refer to the Chinese criteria for adults, waist circumference was categorized into two groups: < 90/85 cm and ≥ 90/85 cm, in men/women[12].

Covariates

Demographic characteristics

The demographic variables included age, sex, residence setting (rural vs. urban), height (cm), weight (kg), and BMI (kg/m^2). BMI was calculated using body weight divided by the square of height. Refer to the Chinese criteria for adults, BMI ≥ 24 kg/m^2 and BMI ≥ 28 kg/m^2 were defined as overweight and obesity, respectively[14,15]. Due to the small number of obese individuals included, BMI was categorized as < 24 kg/m^2 and ≥ 24 kg/m^2.

Health-risk behaviors
Health-risk behaviors included smoking status (current, former, none), alcohol drinking status (current, former, none), sleeping status (good, fair, poor) and physical activity. Physical activity was divided into three intensities: vigorous, moderate, and low. Vigorous physical activity included moving heavy objects, digging, farming, aerobic exercise, fast cycling, and cycling to load goods; moderate physical activity included moving lightweight objects, cycling at regular speeds, mopping the floor, practicing Tai Chi, brisk walking, etc.; low physical activity included walking, including walking from one place to another while working or at home, taking other walks for leisure, exercise, exercise, or entertainment. According to the International Physical Activity Questionnaire Short Version[16], physical activity was categorized into three levels: low physical activity (3.3 metabolic equivalents [METs]), moderate physical activity (4.0 METs) and vigorous physical activity (8.0 METs). The total physical activity per week was calculated by multiplying the MET by the duration and frequency during one week.

Physical status
Chronic disease including hypertension, dyslipidemia, diabetes or high blood sugar, cancer or malignant tumor, liver disease, cardiovascular disease, stroke, kidney disease, stomach or other digestive disease, psychiatric disease, memory-related disease, arthritis or rheumatism, and asthma were assessed based on self-reported physician diagnosis. For each chronic disease, participants were responded "yes" or "no". The number of other diagnosed comorbidities were assessed.

Statistical analysis
SPSS version 22.0 (IBM Corp, NY, 2012) and Mplus (version 8.0; Muthén & Muthén, Los Angeles, CA) were used for statistical analysis. Baseline characteristics were performed with descriptive analyses. Continuous variables were represented by Mean and standard deviation (Mean ± SD) or median and interquartile distance (M[Q25, Q75]), and categorical variables were represented by frequencies (%). Latent class growth analysis (LCGA), a statistical method for analyzing longitudinal data derived from conventional growth modeling, was used to identify distinct PEF trajectories. The basic assumption of the LCGA was that there were potential subgroups with heterogeneous trajectories among study subjects, and the model could explore the number of potential subgroups and the trajectories of each subgroup. LCGA summarized similar individual trajectories into a group, reflecting the classification of developmental changes of each individual. LCGA aimed to characterize the numbers and characteristics of these individuals through the identification of the k number of distinct latent classes (i.e., subgroups), which were PEF trajectories in the current study. Each of these identified classes exhibits particular growth parameters (slope, intercept) that are assumed to be latent[17]. Optimal numbers of latent classes were determined based upon Likelihood values, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Bootstrapped likelihood ratio test (BLRT), entropy, and percent of participants per class values. For likelihood values, with higher values being indicative of better fit. AIC and BIC values were considered, with lower values being indicative of better model fit. For Entropy, the closer the value was to 1, the more accurate the classification. BLRT values were taken into consideration, with values less than 0.05 indicates that the model is classified into class n significantly better than class n-1. After the trajectories were determined, the posterior probability of the research object entering each trajectory is calculated, and the research object was assigned to the trajectory according to the maximum posterior probability. According to previous studies, the posterior probability was set to be greater than 0.7 in the current study[18,19]. Independent sample t test or non-parametric test were used to compare continuous data between PEF trajectories. Chi-square or Fisher exact test were used to compare categorical data between PEF trajectories. The multiple logistic regression was used to assess the association between waist circumference and PEF trajectories. A two-sided $P < 0.05$ was the threshold of statistical significance.

Results
The inclusion process of patients with COPD
A total of 775 patients with COPD were included in the current study. The inclusion process was shown in Fig. 1. In 2011, 1,781 patients with COPD were included in the CHARLS cohort. In total, 1,384 patients with COPD aged 45 years or older completed baseline PEF assessment, of whom 856,635, and 1,034 completed the first follow-up survey, the second follow-up survey, and either the first or second follow-up survey, respectively. Of 1034 study subjects, 871 patients completed waist circumference assessments, of whom 563, 588, and 775 completed the first follow-up survey, the second follow-up survey, and either the first or second follow-up survey, respectively. Finally, the current analysis was conducted among the 775 participants.

Patient characteristics
Patient baseline characteristics were shown in Table 1. At baseline, 775 participants had an average age of 53.66 years, of which 195 (58.45%) were male. Among them, 369 participants (47.61%) reported living in urban areas, and 301 participants (38.84%) were abdominal obesity. The characteristics of included patients in 2013 and 2015 was shown in Supplementary Table 1.

The data on included and excluded patients was shown in Supplementary Table 2. From 2011 to 2015, the mean PEF value showed a decreasing trend, with respective average values at these time points of 205.84 L/min (SD = 104.16), 199.99 L/min (SD = 99.52), and 196.06 L/min (SD = 86.74). There was a significant difference in the PEF from 2011 to 2015 (Wald$\chi^2 = 6.348$, $P = 0.042$).

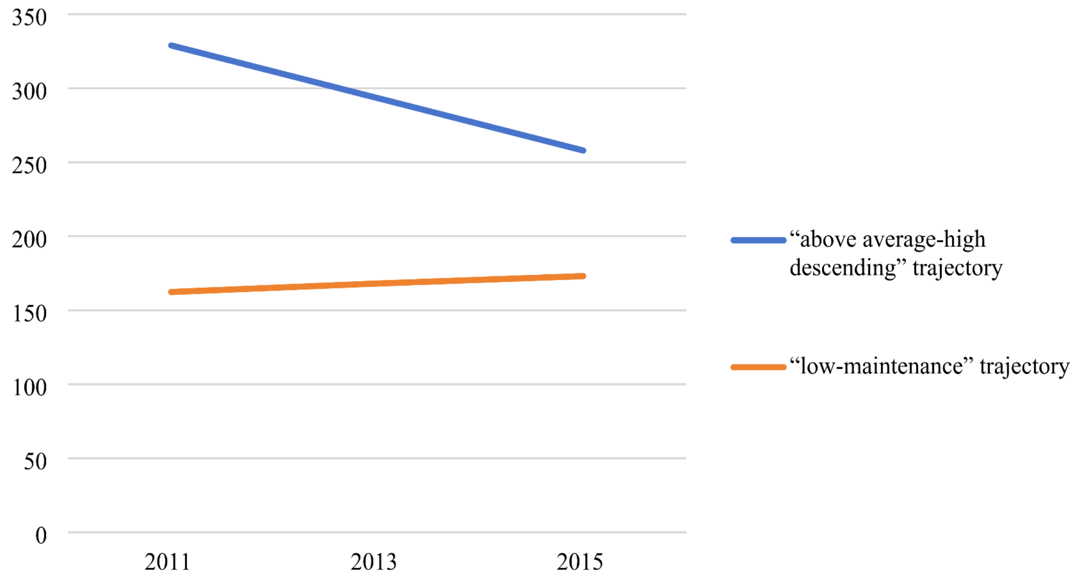

Fig. 1. The pulmonary function trajectories of patients with COPD.

Identifying pulmonary function trajectories

Classification fit statistics were showed in Table 2. When increasing from a one-class to a four-class model, AIC, BIC and entropy values declined, while the BLRT was statistically significant ($P<0.001$). Therefore, the two-class model was chosen based on goodness-of-ft indices. The developed three- and four-class models were not convergent. Based on the observed characteristics of these distributions, the two identified PEF trajectories were defined as "low-maintenance" trajectory ($n=588$, 75.74%) and "above average-high descending" trajectory ($n=187$, 24.13%). The PEF trajectories were shown in Fig. 1. In the "low-maintenance" trajectory, patients with COPD had lower PEF at baseline and remained low during follow-up. In the "above average-high descending" trajectory, the PEF of patients with COPD was higher than those in the "low-maintenance" trajectory. In the "above average-high descending" trajectory, the PEF of patients with COPD showed a significant decreased trend from 2011 to 2015.

The effect of abdominal obesity on pulmonary function trajectories

Table 3 showed the distribution of PEF trajectories among patients with COPD. Compared with the "above average-high descending" trajectory, the patients in the "low-maintenance" trajectory were older ($P=0.011$). Moreover, compared with participants in rural settings, those living in urban areas were more likely to be classified under the "low-maintenance" trajectory ($P=0.007$). Additionally, higher waist circumference ($P<0.001$) and BMI ($P=0.012$) were linked to participants being classified under the "low-maintenance" trajectory.

Unadjusted analysis showed that age, residence setting, BMI and abdominal circumference were associated with the PEF trajectories (Table 3). However, considering the influence of gender on pulmonary function, gender was also adjusted in logistic regressions. Therefore, according to the significance and clinical value of the predictors, the final variables included in the logistic regressions included age, gender, residence, BMI and abdominal circumference. The logistic regressions of PEF trajectories among patients with COPD was shown in Table 4. Using the "above average-high descending" trajectory as a reference group, a multiple logistic regression was conducted to identify the association between abdominal circumference and PEF trajectories. The analysis revealed that baseline higher waist circumference was associated with an increased risk of participants being classified under the "low-maintenance" trajectory (OR = 2.248, $P<0.001$), after adjusting for age, gender, residence setting, and BMI.

Discussion

To our knowledge, this was the first study to explore pulmonary function over a 4-year period among middle-aged and older patients with COPD in China. In our study, two distinct pulmonary function trajectories were identified: the "low-maintenance" trajectory and "above average-high descending" trajectory. Notably, after controlling for confounding factors, a negative association between abdominal obesity and pulmonary function trajectories was observed among patients with COPD. Specifically, those with a larger waist circumference had a 2.248-fold increased risk of being classified into the "low-maintenance" trajectory compared to those with normal waist circumference. This suggests that increased abdominal fat may contribute to the decline of pulmonary function over time.

Our findings were consistence with previous studies that have shown a negative association between abdominal obesity and pulmonary function. Choe et al. found that the baseline visceral adipose tissue (VAT) was inversely associated with pulmonary function in both males and females[20]. Similarily, Kawabata et al. reported

Characteristics	Mean ± SD/n(%)
Age, years	53.66 ± 4.76
Gender	
Male	453 (58.45)
Female	322 (41.55)
Residence	
Urban	369 (47.61)
Rural	406 (52.39)
Smoking	
Never	537 (69.29)
Former	78 (10.06)
Current	160 (20.65)
Drinking	
Never	475 (61.29)
Former	113 (14.58)
Current	187 (29.85)
Physical activity, MET	116.93 ± 42.02
Number of chronic disease	
1–2	325 (41.94)
≥ 3	450 (58.06)
Cooking fuel	
Clean	480 (61.94)
Non-clean	287 (37.03)
Others	8 (1.03)
Heating fuel	
Clean	542 (69.94)
Non-clean	117 (15.10)
Others	116 (14.97)
BMI, kg/m^2	
< 24	622 (80.26)
≥ 24	153 (19.74)
Waist circumference(male/female), cm	
< 85/90	474 (61.16)
≥ 85/90	301 (38.84)

Table 1. The characteristics of patients with COPD in 2011(N = 775). MET, metabolic equivalent; BMI, body mass index.

Class	Likelihood	AIC	BIC	Entropy	BLRT	Probability			
						1	2	3	4
1	− 13920.852	27851.704	27874.968	–	–	–			
2	− 13748.980	27513.960	27551.183	0.747	< 0.001	0.742	0.258		
3	− 13724.635	27471.270	27522.452	0.734	0.367	0.636	0.054	0.310	
4	− 13703.445	27434.890	27500.030	0.727	0.085	0.101	0.331	0.026	0.542

Table 2. Fit statistics of latent profile analysis.

significant negative correlations between waist circumference and FVC% predicted in younger females, even after controlling for confounders[21].

Several mechanisms may explain the association between abdominal obesity and impaired pulmonary function. First, excessive abdominal fat could restrict the movement of the diaphragm and chest, thereby reducing lung and chest compliance[22]. The restriction may lead to ventilation dysfunction, hypoxia, and shortness of breath[22]. Additionally, obesity affects the structure and function of the respiratory tract and airway. Fat deposition around the airways reduces the inner diameter of the upper airways, contributing to airway obstruction, which further hinders pulmonary function[23,24]. Another potential explanation is the elevation of the diaphragm in obese individuals, which may restrict the expansion of the lower lungs, and potentially lead to atelectasis in the lung bases[23,24]. Moreover, abdominal fat accumulation limits the movement of diaphragm and chest wall, restricting full lung expansion. This restriction could reduce ventilation in certain lung regions,

Characteristics	Low-maintenance group(n = 588)	Above average-high descending group(n = 187)	P^{a}
	Mean ± SD/n(%)	Mean ± SD/n(%)	
Age, years	53.90 ± 4.70	52.89 ± 4.89	**0.011**
Gender			0.671
Male	341 (57.99)	112 (59.89)	
Female	247 (42.01)	75 (40.11)	
Residence			**0.007**
Urban	292 (49.66)	114 (60.96)	
Rural	296 (59.34)	73 (30.04)	
Smoking			0.098
Never	419 (71.26)	118 (63.10)	
Former	54 (9.18)	24 (12.83)	
Current	115 (19.56)	45 (24.06)	
Drinking			0.582
Never	366 (62.24)	109 (58.29)	
Former	85 (14.46)	28 (14.97)	
Current	137 (23.30)	50 (26.74)	
Physical activity, MET	117.33 ± 41.89	115.61 ± 42.56	0.628
Number of chronic diseases			0.661
1–2	244 (41.50)	81 (43.32)	
≥ 3	344 (58.50)	106 (56.68)	
Cooking fuel			0.667
Clean	364 (61.90)	116 (62.03)	
Non-clean	219 (37.24)	68 (36.36)	
Others	5 (0.85)	3 (1.60)	
Heating fuel			0.249
Clean	416 (70.75)	126 (67.38)	
Non-clean	91 (15.48)	26 (13.90)	
Others	81 (13.78)	35 (18.72)	
BMI, kg/m^2			0.012
< 24	460 (78.23)	162 (86.63)	
≥ 24	128 (21.77)	25 (13.37)	
Waist circumstance (male/female), cm			< 0.001
< 85/90	332 (56.46)	142 (75.94)	
≥ 85/90	256 (43.54)	45 (24.06)	

Table 3. Distribution of PEF trajectories among patients with COPD. MET, metabolic equivalent; BMI, body mass index. Significant values are in bold.

	β	OR	95% CI	P
Age, years	0.043	1.044	1.008–1.082	0.017
Gender				
Male		Reference		
Female	0.036	1.037	0.734–1.465	0.836
Residence				
Urban		Reference		
Rural	0.429	1.536	1.090–2.164	0.014
Waist circumstance (male/female), cm				
< 90/85		Reference		
≥ 90/85	0.810	2.248	1.511–3.345	< 0.001
BMI				
< 24		Reference		
≥ 24	0.215	1.240	0.752–2.044	0.399

Table 4. The logistic regressions of PEF trajectories among patients with COPD.

leading to restrictive ventilation dysfunction[23,24]. Although pulmonary blood flow distribution in obese individuals is similar to that in normal-weight individuals, the imbalance between ventilation and perfusion caused by restrictive ventilation dysfunction leads to a decline in lung diffusion capacity, ultimately contributing to the deterioration of pulmonary function[23]. These findings suggest the importance of addressing abdominal obesity in the rehabilitation of patients with COPD. Interventions such as exercise training, which could help to reduce abdominal fat, may play a critical role in improving pulmonary function. Our results provide valuable insights for future research on pulmonary function interventions and contribute to the rehabilitation of respiratory diseases.

While BMI was a common indicator of fat accumulation, our study did not find a significant association between BMI and pulmonary function trajectories in COPD patients. This may be due to the fact that BMI is a relatively crude measure, reflecting total body fat and muscle mass, but not accounting for the distribution of fat. In contrast, waist circumference is a more accurate indicator of abdominal fat accumulation, which may explain why it was associated with pulmonary function trajectories, while BMI was not.

Limitations

There are several limitations in the current study. Firstly, while previous studies have observed several distinctive pulmonary function trajectories[25,26], our study found only two trajectories, possibly due to the relatively short follow-up period. Additionally, the CHARLS survey did not include pulmonary function indicators other than PEF. Future studies should incorporate more comprehensive pulmonary function measures, such as FEV1 and FVC. Moreover, since the CHARLS survey did not provide information on COPD severity or type, we were unable to account for these factors in our analysis. Finally, our study only included individuals aged 45 years and older, which limits the generalizability of the findings to a broader population.

Conclusions

To conclude, the negative association between abdominal obesity and pulmonary function trajectories was observed among patients with COPD. For patients with COPD of abdominal obesity, it is necessary to take appropriate measures such as exercise training to prevent the the progressive decline of pulmonary function. Future randomized controlled trials could be used to explore the effect of exercise training on improving pulmonary function in patients with COPD of abdominal obesity.

Data availability

The datasets generated and/or analysed during the current study are available in the [CHARLS] repository, [http://charls.pku.edu.cn].

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Author contributions
SSS, HBC, MP and CW conceptualized the study, CW collected data, CW, YMW and WZ analyzed data, CW wrote the manuscript. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
All participants signed an informed consent. The survey has approved by the Institutional Review Board (IRB) at Peking University (IRB approval number: IRB00001052-11015).

Additional information
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