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Path analysis of predictors of frailty in hospitalised patients with chronic obstructive pulmonary disease

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Frailty is highly prevalent in elderly patients with chronic obstructive pulmonary disease (COPD), contributing to poor clinical outcomes and reduced quality of life. To examine the effects of grip strength, CAT score, multimorbidity, GOLD stage, and age on frailty for hospitalised elderly with COPD through path analysis. This cross-sectional study used convenience sampling to select 283 hospitalised patients from March to August 2024. Path analysis explored the direct and indirect effects among grip strength, CAT score, multimorbidity, GOLD stage, and age. Grip strength was measured with a digital dynamometer, CAT score assessed disease impact, multimorbidity was based on patient-reported diagnoses, and GOLD stage was determined by pulmonary function tests. Among 283 hospitalised elderly COPD patients, the prevalence of frailty was 33.92%. The path analysis model showed good fit (χ^2/df = 1.170, RMSEA = 0.027, 90% CI = 0.024–0.085, CFI = 0.992, TLI = 0.982, SRMR = 0.051, GFI = 0.981). Grip strength was the strongest predictor of frailty, followed by multimorbidity. The model explained 46.9% of the variance in frailty, with grip strength accounting for 11.2%. Hospitalised elderly patients with COPD who exhibited low grip strength, high CAT score, advanced age, multimorbidity, and a higher GOLD stage were more likely to experience frailty. These findings suggest that interventions aimed at improving grip strength and managing multimorbidity may help alleviate frailty in elderly COPD patients.

Keywords Chronic obstructive pulmonary disease, Hospitalised patients, Frailty factors

Chronic obstructive pulmonary disease is a prevalent chronic condition among the elderly, characterised by high morbidity and mortality rates worldwide[1]. It accelerates lung damage and ageing through abnormal repair mechanisms driven by oxidative stress[2]. Respiratory dysfunction is closely linked to frailty, therefore, elderly patients with COPD are more likely to develop frailty[3]. Studies have reported an average frailty prevalence of 47.0% among hospitalised elderly patients with COPD in other countries[4], while in hospitalised elderly individuals in China, the prevalence is 25.0%[5]. Frailty is further associated with advanced age, muscle loss, the coexistence of multiple chronic conditions, and a decline in the ability to perform activities of daily living[6–8]. When frailty and COPD coexist, they exacerbate negative outcomes such as sarcopenia, falls, disability, hospitalisation, and mortality[9]. However, most previous studies have not fully elucidated the interactions among high-risk factors for frailty, the relative strength of their effects, or the presence of direct or indirect mediating factors in hospitalised elderly patients with COPD.

The cycle of frailty theory[10] and the integrated conceptual model of frailty[11] are widely accepted frameworks for explaining frailty. The cycle of frailty theory describes a vicious cycle in which the coexistence of multiple diseases increases energy expenditure, leading to decreased muscle strength and reduced walking speeds[12]. Frailty is recognised as a dynamic and continuous process influenced by physical, psychological, and social factors[13]. Potential indirect effects may arise along pathways involving decreased muscle strength and the coexistence of multiple chronic diseases, two major geriatric syndromes that are strongly associated with the onset of frailty and exhibit bidirectional relationships. Recent evidence suggests that elderly patients with COPD with below-normal muscle strength are significantly more likely to develop frailty[14]. Additionally, the progressive decline in muscle mass, bone density, and cardiorespiratory fitness in elderly individuals substantially increases frailty risk[15].

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The simultaneous occurrence of muscle strength decline and multimorbidity is common in late life, particularly in population-based studies. Most patients with COPD have at least one comorbid condition[16], and those with multimorbidity experience significantly higher frailty and mortality rates than those without[17]. Sarcopenia is also prevalent among older COPD patients, with reported rates of 24% in Asia[18], and 15% in Europe[19]. Both low muscle strength and multimorbidity are associated with adverse health outcomes, including falls, hospitalisation, institutionalisation, and death[20]. These conditions also contribute to poor quality of life, often reflected in impaired CAT scores[21–23]. Their combined effects exacerbate these adverse outcomes, highlighting the need for further research into their shared pathological mechanisms, potential interactions, and predictive roles. Such investigations could provide valuable insights into the prevention and management of frailty in elderly patients with COPD.

In summary, this study aims to investigate the interrelationships among key high-risk factors closely associated with frailty—namely grip strength, multimorbidity, CAT score, GOLD stage, and age—and to examine their impact on frailty in hospitalised elderly patients with COPD. The findings aim to provide a scientific basis for advancing clinical understanding of the factors influencing frailty.

Methods

Conceptual framework of the study

In this study, on the basis of the cycle of frailty theory and the integrated conceptual model of frailty, we integrated its aggregated factors—grip strength, multimorbidity, CAT score, GOLD stage and age to construct a theoretical hypothesis model. This model was used to analyse the interactions among these factors, as well as their direct and indirect effects on frailty in hospitalised elderly patients with COPD. In summary, this study proposes the following theoretical hypotheses (Fig. 1):

Hypothesis 1 Age directly affects frailty.

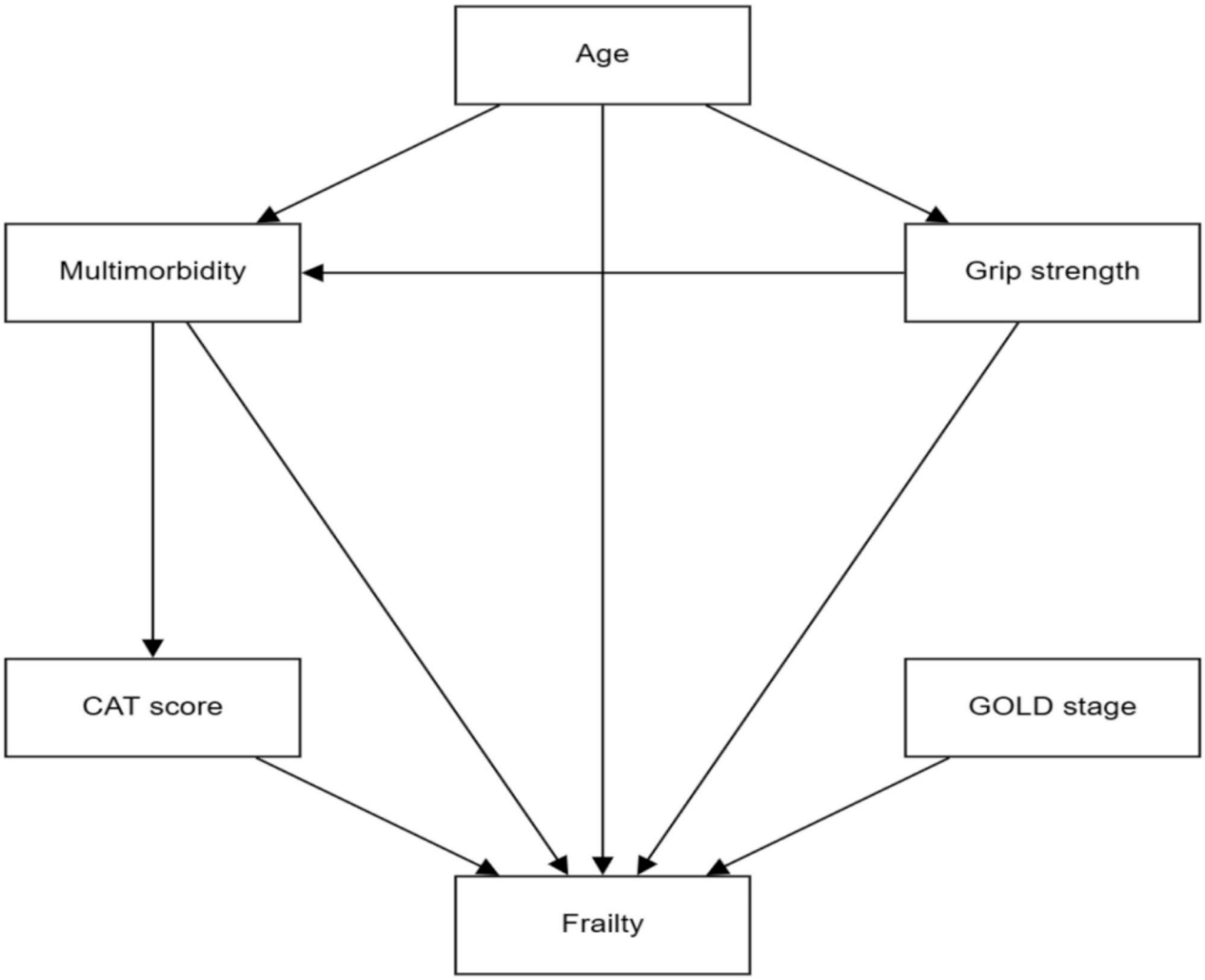

Fig. 1. Theoretical hypothetical model.

Hypothesis 2 Grip strength directly affects frailty.

Hypothesis 3 The CAT score directly affects frailty.

Hypothesis 4 Multimorbidity directly affects frailty.

Hypothesis 5 GOLD stage directly affects frailty.

Hypothesis 6 Age indirectly affects frailty through multimorbidity.

Hypothesis 7 Age indirectly affects frailty through grip strength.

Hypothesis 8 Grip strength indirectly affects frailty through multimorbidity.

Hypothesis 9 Multimorbidity indirectly affects frailty through the CAT score.

Study design and population

This study employed a cross-sectional design with convenience sampling to recruit participants. Data were collected from the First Affiliated Hospital of Chongqing Medical University, involving 283 patients between March and August 2024. Data were collected within 48 h after the attending physician issued the pre-discharge order, once patients met the hospital's standardised discharge criteria for COPD, ensuring clinical stability and minimising symptom fluctuations during hospitalisation. Baseline data were collected using a general form. Frailty was assessed via the FRAIL scale, grip strength measured with the XiangShan EH101 device, CAT score used to evaluate disease impact, and GOLD stage determined by pulmonary function tests. Path and mediation analyses explored the relationships between these variables and frailty in hospitalised elderly COPD patients.

The study considered 11 parameters, with 20 observations for each parameter, yielding a minimum required sample size of 220. The final sample size included 283 cases, ensuring adequate statistical power[24]. Inclusion criteria were: (a) age ≥ 65 years; (b) diagnosis of COPD based on the GOLD guidelines (2024 edition); and (c) voluntary participation with informed consent. Exclusion criteria included: (a) speech disorders, cognitive impairment, or physical activity limitations (such as severe mobility restrictions, dependence on a wheelchair or bedridden status)[25]; and (b) inability to complete the FRAIL assessment.

All participants provided written informed consent. The study was conducted according to the Declaration of Helsinki and approved by the Ethics Committee of the Chongqing Medical University First Affiliated Hospital Clinical Research (No. 2024-224-01).

Measures

Demographic variables

A general data collection form, designed by the research team, was used to document demographic and clinical characteristics, including age, gender, marital status, education level, living arrangements, BMI (body mass index), lung function, CAT score, multimorbidity, grip strength, and frailty status. Patients provided personal demographic information, while clinical data were extracted from electronic medical records. Data collection was conducted in the ward by a postgraduate researcher and a clinical nurse, data collection forms were retrieved immediately after completion. All collected materials were strictly used for research purposes.

Chronic Obstructive Pulmonary Disease Assessment Test (CAT scale)

The CAT scale, introduced by Jones in 2009, quantifies the impact of COPD to facilitate health status assessment and improve communication between patients and clinicians[14]. This self-reported scale consists of eight items addressing cough, sputum production, chest tightness, dyspnoea, activity limitations, confidence in leaving the home, sleep quality, and energy levels. Each item is scored on a 0 to 5 scale, with a total score ranging from 0 to 40. Higher scores indicate greater disease impact. Assessment categories were as follows: ≤ 10 (mild impact), 11–20 (moderate impact), 21–30 (severe impact), and > 30 (very severe impact). The Chinese version of the CAT scale has demonstrated robust internal consistency and validity in the local population, with a Cronbach's alpha coefficient of 0.805[26].

Hand grip strength

Grip strength was assessed using a digital measuring device (XiangShan EH101, China). Patients were instructed to exert maximum grip strength with their dominant hand over 30 s to one minute per measurement. The highest value from three consecutive attempts was recorded for analysis[27].

FRAIL scale

Frailty levels were evaluated using the FRAIL scale, a simple and practical self-assessment tool developed from the Fried frailty phenotype[10]. The scale comprises five components: fatigue, resistance, ambulation, illness, and weight loss. Each "yes" response scores 1 point, yielding a total score between 0 and 5. Scores are categorised as follows: 0 (robust), 1–2 (prefrail), and ≥ 3 (frail). The Chinese version of the FRAIL scale has shown satisfactory validity and reliability in community-dwelling older adults[28].

GOLD stage

The GOLD stage are determined based on the patient's pulmonary function test results. The classification is as follows: Grade 1 (Mild): $FEV_1 \geq 80\%$ of the predicted value; Grade 2 (Moderate): $50\% \leq FEV_1 \leq 80\%$ of the

predicted value; Grade 3 (Severe): 30% ≤ FEV_1 < 50% of the predicted value; Grade 4 (Very Severe): FEV_1 < 30% of the predicted value[29].

Statistical analyses

Statistical analyses were performed using IBM SPSS 26.0. Continuous variables conforming to a normal distribution were described as means and standard deviations (mean ± SD), whereas non-normally distributed variables were expressed as medians and interquartile ranges M(IQR). The Kolmogorov–Smirnov test was used to assess the normality of continuous variables. Pearson correlation analysis was used for variables with a normal distribution, while Spearman's rank correlation was used for non-normally distributed variables to explore relationships between variables. Categorical variables were compared using the chi-square test, and continuous variables were compared using either the independent samples t-test or the Mann–Whitney U test according to their distribution. All statistical tests were two-tailed, and a $p < 0.05$ was considered statistically significant.

Path analysis was performed using IBM SPSS AMOS 26.0 to evaluate the hypothetical model, with maximum likelihood estimation used to estimate model parameters. Mediation models were applied to examine the mediating roles of key variables, and hierarchical regression analysis was employed to validate mediation effects.

Model fit was assessed using standard indices: χ^2/df (< 3.0 acceptable), RMSEA (< 0.08 adequate; < 0.05 good) with 90% CI, CFI and TLI (≥ 0.90 acceptable; > 0.95 good), SRMR (< 0.08 acceptable), and GFI (> 0.90 acceptable). Model estimates were evaluated using critical ratios (CRs), p-values, and bootstrapping to test direct, indirect, and total effects. The study adhered to STROBE guidelines for cross-sectional research.

Results

Characteristics of the study population

A total of 283 participants were included in this study, with a mean age of 68 ± 6.46 years. There were 255 males (90.11%) and 28 females (9.89%). Among all the hospitalised elderly patients with COPD, the incidence of robust is 26.15% (74), prefrail is 39.93% (113), Frailty is 33.92% (96), respectively. (Table 1)

Correlations between frailty variables

Spearman correlation analysis was employed to examine the correlations among variables related to frailty. The results revealed significant correlations among age, multimorbidity, the CAT score, grip strength, and the GOLD stage. Age, CAT score, multimorbidity, and GOLD stage all exhibited positive correlations with frailty, whereas grip strength demonstrated a negative correlation with frailty. Notably, the correlation with frailty was strongest for grip strength (Table 2).

Path analysis

In this study, the maximum likelihood method was used to estimate the parameter of the hypothetical model. The results of the hypothetical model employ standard estimates (β), standard errors (SEs), and critical ratios (CRs), which are the relative effect sizes for each pathway. The parameter estimation, SE, CR values and hypothesis testing of the model revealed that the eight paths were statistically significant (Fig. 2), indicating that the proposed hypotheses were fully supported and that the goodness of fit of the model was generally good: $X^2/df = 1.170$, RMSEA = 0.027, RMSEA 90% CI = 0.024 to 0.085, CFI = 0.992, TLI = 0.982, SRMR = 0.051, GFI = 0.981, indicating that the model had good applicability to the sample data and analysis of this study.

Age (β = 0.173, $p < 0.01$), the CAT score (β = 0.221, $p < 0.01$), multimorbidity (β = 0.239, $p < 0.01$), GOLD stage (β = 0.161, $p < 0.01$) and grip strength (β = -0.352, $p < 0.01$) had direct impacts on frailty. Age, multimorbidity, GOLD stage, and CAT score were positively associated with frailty, indicating that increased age, a higher number of comorbidities, elevated CAT scores, and more advanced GOLD stage may exacerbate the severity of frailty. Grip strength has a negative effect on frailty, and the absolute value of the standardized path coefficient is the largest, indicating that grip strength has the greatest direct effect on frailty. (Table 3)

Mediating effects analysis of factors influencing hospitalised elderly patients with COPD

The mediating effects analysis of the variables in the model are shown in Table 4. Age, multimorbidity, GOLD stage, and grip strength not only had direct effects on frailty but also exerted partial mediated effect on frailty. The total effects of age, multimorbidity status and grip strength on frailty were 0.098, 1.434 and − 0.108 respectively ($P < 0.01$). The mediating effect proportion of grip strength was 21.916%, multimorbidity was 17.106%, CAT score was 17.253%, multimorbidity was 12.846% and GOLD stage was 6.831%.

Hierarchical regression analysis of variables

The hierarchical regression results for age, multimorbidity, CAT score, GOLD stage, and grip strength in hospitalised elderly COPD patients are shown in Table 5. These variables jointly explained 46.9% of the variance in frailty. In Model 1, age alone explained 10.8% of the variance ($R^2 = 0.108$). Adding multimorbidity in Model 2 increased R^2 to 0.203 ($\Delta R^2 = 9.4\%$). In Model 3, the inclusion of CAT score raised R^2 to 0.276 ($\Delta R^2 = 7.3\%$). Grip strength, added in Model 4, contributed the largest increase, raising R^2 to 0.388 ($\Delta R^2 = 11.2\%$). Finally, adding GOLD stage in Model 5 increased R^2 to 0.470, accounting for an additional 8.2% of the variance.

Discussion

This study is the first to examine the independent and mediating effects of age, grip strength, CAT score, GOLD stage, and multimorbidity on frailty in hospitalised older adults with COPD. These factors jointly explained 46.9% of frailty variance, with grip strength having the strongest effect (11.2%) and the greatest negative direct impact (β = -0.352, $p < 0.01$). Although not included in the FRAIL scale, grip strength is a core component of Fried's

Variables	*N*	%
Age (years, mean ± SD)	68.074 ± 6.46	
Grip strength (kg, mean ± SD)	22.614 ± 8.31	
BMI (kg/m^2, mean ± SD)	21.827 ± 4.05	
Gender		
Male	255	90.11
Female	28	9.89
Marital status		
Married	262	92.58
Single	21	7.42
Education		
Primary school and below	2	0.71
Primary school	104	36.75
Junior high school	110	38.87
High school and above	67	23.67
Living status		
Yes	20	7.07
No	263	92.93
Multimorbidity		
Yes	148	47.70
No	135	52.30
CAT score		
Slight impact	89	31.45
Moderate impact	44	15.55
Severe impact	73	25.80
Very severe impact	77	27.21
GOLD stage		
1	82	28.98
2	83	29.33
3	67	23.67
4	51	18.02
Frail		
Robust	74	26.15
Prefrail	113	39.93
Frailty	96	33.92

Table 1. The demographic and clinical characteristics of all participants ($N = 283$). *SD* standard deviation.

	Frail	Age	Multimorbidity	CAT score	Grip strength	GOLD stage
Frail	1					
Age	0.349**	1				
Multimorbidity	0.387**	0.216**	1			
CAT score	0.357**	0.107	0.223**	1		
Grip strength	− 0.459**	− 0.214**	− 0.220**	− 0.145*	1	
GOLD stage	0.269**	0.051	0.171**	0.082	− 0.018	1

Table 2. Correlation analysis between independent variables. *$p < 0.05$ **$p < 0.01$.

frailty phenotype and a validated marker of physical frailty[10]. Our findings move beyond identifying associations to quantifying explanatory power, underscoring grip strength's central role in frailty. We also identified intricate interactions among risk factors. Age-related muscle loss contributes to grip strength decline and multimorbidity, both of which elevate frailty risk[30–32]. Low grip strength has been linked to poorer quality of life, multimorbidity, and higher mortality[33,34]. While age, multimorbidity, CAT score, and GOLD stage influence frailty, grip strength exerts a more substantial impact. Additionally, multimorbidity worsens respiratory symptoms, reflected in higher CAT scores, which are themselves strong predictors of frailty[21,22].

For hospitalised elderly patients with COPD, disease severity is a critical factor influencing the development of frailty. These individuals are particularly vulnerable to frailty during exacerbations, which also contribute to

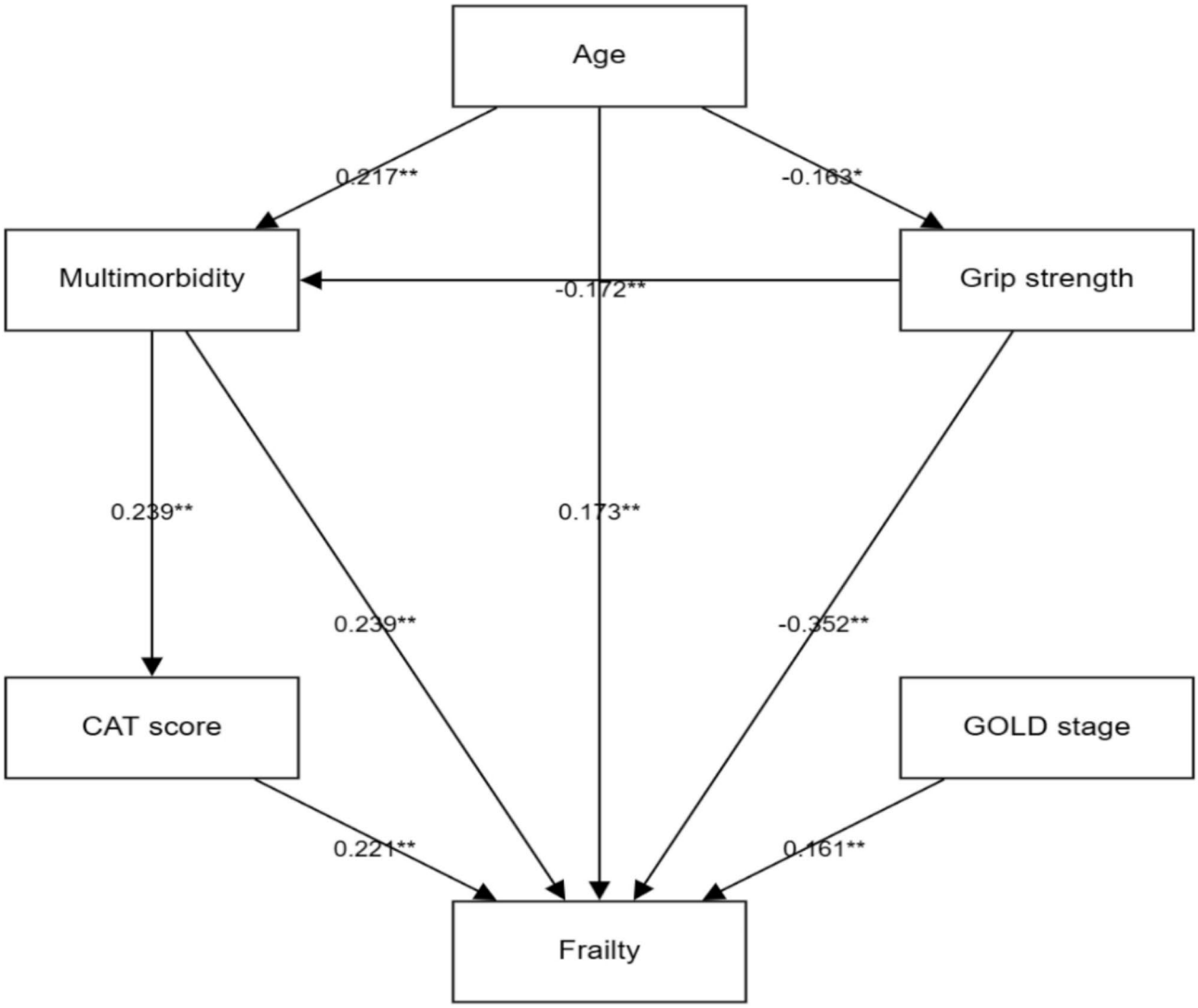

Fig. 2. Standardized coefficients of path analyses model for factors influencing hospitalised elderly patients with COPD.

X	→	Y	Unstandardized path coefficient	SE	C.*R.*	*p*	Standardized path coefficient
Age	→	Frail	0.051	0.016	3.269	0.001	0.173
CAT Score	→	Frail	0.358	0.085	4.205	<0.01	0.221
Multimorbidity	→	Frail	0.898	0.206	4.354	<0.01	0.239
Grip Strength	→	Frail	− 0.079	0.012	− 6.716	<0.01	− 0.352
Multimorbidity	→	CAT Score	0.555	0.148	3.740	<0.01	0.239
Age	→	Multimorbidity	0.017	0.005	3.406	0.001	0.217
Grip Strength	→	Multimorbidity	− 0.010	0.004	− 2.688	0.007	− 0.172
Age	→	Grip Strength	− 0.214	0.085	− 2.504	0.012	− 0.163
GOLD stage	→	Frail	0.294	0.093	3.153	0.002	0.161

Table 3. Parameter estimates of variables for the structural equation model ($n = 283$). Note: The arrow (→) indicates the path influence relationship. S.E = standard error; C.R.= critical ratio.

elevated overall mortality rates[5,35]. GOLD stage directly affected frailty (β = 0.161, $p < 0.01$) and had a modest indirect effect via multimorbidity (6.831%, 95% CI: 0.004–0.066), suggesting additional latent mechanisms may be at play[36,37]. Despite controlling for key covariates, residual confounding cannot be ruled out. Longitudinal studies are needed to better delineate these pathways.

Path	Total effect	Mediating effect	Direct effects	Effect proportion	Mediating effect (95% CI)	Test conclusion
Age ⇒ Grip strength ⇒ Frail	0.098**	0.021	0.060**	21.916%	− 0.393 to − 0.098	Partial intermediary
Age ⇒ Multimorbidity ⇒ Frail	0.098**	0.017	0.060**	17.106%	0.009 to 0.026	Partial intermediary
Multimorbidity ⇒ CAT score ⇒ Frail	1.434**	0.247	1.187**	17.253%	0.000 to 0.042	Partial intermediary
Grip strength ⇒ Multimorbidity ⇒ Frail	− 0.108**	− 0.014	− 0.094**	12.846%	− 0.103 to − 0.024	Partial intermediary
Multimorbidity ⇒ GOLD stage ⇒ Frail	1.635**	0.112	1.523**	6.831%	0.004 to 0.066	Partial intermediary

Table 4. The direct, indirect and total effects of variables in the structural equation model ($n = 283$). *$p < 0.05$ **$p < 0.01$ Bootstrap type = Percentile bootstrap method.

Model	Variables	R^2 (adjusted)	F-value	*P*-value	B-value	T-value
1	Age	0.108	34.155	<0.01	0.329	5.844
2	Model 1 + Multimorbidity	0.203	35.589	0.001	0.315	5.755
3	Model 2 + CAT Score	0.276	35.479	<0.01	0.460	5.321
4	Model 3 + Grip Strength	0.388	44.124	<0.01	− 0.081	− 7.141
5	Model 4 + GOLD stage	0.470	49.208	<0.01	− 0.247	6.552

Table 5. Hierarchical regression analysis. *$p < 0.05$; B-value: standardized regression coefficient.

Our mediation analysis confirmed that grip strength, multimorbidity, GOLD stage and CAT score partially mediated the effects of risk factors on frailty, with grip strength showing the highest mediating proportion. These factors interact synergistically, and failure to manage them can significantly compromise quality of life and burden healthcare systems[38,39], Fortunately, frailty is reversible[40,41], and targeted interventions addressing modifiable risks can mitigate its impact.

Current frailty management often follows generic guidelines that lack stratification, limiting clinical applicability, particularly in patients with reduced exercise tolerance[42,43]. Our findings offer actionable insights into key frailty determinants—grip strength, CAT score, multimorbidity, GOLD stage, and age—supporting early risk identification and personalised intervention. Such strategies can reduce rehospitalisation, enhance life quality, and ease the burden on healthcare systems[44,45], representing a meaningful advancement in the management of frailty in hospitalised elderly COPD patients.

Limitations and strengths

This study has several limitations. First, its cross-sectional design limits causal interpretations and cannot capture longitudinal changes in the variables associated with frailty. Second, the sample was predominantly male, with relatively few female participants. While this reflects the higher COPD prevalence among older men, the gender imbalance may introduce bias and limits generalisability to female patients. The small number of women also prevented gender-stratified analyses, potentially obscuring sex-specific associations with frailty.

To our knowledge, this is the first study to assess the relative contributions of age, grip strength, CAT score, multimorbidity, and GOLD stage to frailty in hospitalised elderly COPD patients. Our results offer valuable evidence to inform targeted frailty interventions aimed at improving clinical outcomes in this high-risk population.

Conclusion

This study demonstrates that hospitalised elderly patients with COPD often present with reduced grip strength, multimorbidity, elevated CAT scores, higher GOLD stages, and advanced age—factors significantly associated with frailty. Advancing age leads to decreased muscle strength and a higher risk of chronic diseases, thereby contributing to the development of frailty. Additionally, GOLD stage mediates the effect of multimorbidity, while multimorbidity mediates the effect of CAT score on frailty. Although path analysis confirmed these complex interrelationships, their temporal and causal dynamics require validation through longitudinal studies. Such research would support the design of targeted interventions to improve outcomes and ease the burden on healthcare systems.

Data availability

All the data analysed during this study are included in this published article.

Received: 28 January 2025; Accepted: 21 April 2025
Published online: 28 April 2025

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Acknowledgements

The authors would like to thank The First Hospital of Chongqing Medical University for their collaboration in

providing the research population.

Author contributions
All the authors participated in the article preparation. The authors read and approved the final manuscript. Study concept and design: HJ, YH. Data collection: HJ, YY. Analysis and interpretation of data: HJ, LP. Drafting the manuscript: HJ. Revision of the manuscript: HJ, YH, LP, YY.

Funding
The study was supported by the Key Discipline Construction Project of the School of Nursing, Chongqing Medical University (project no. 20240301) and the Nursing Research and Innovation Project of the First Affiliated Hospital of Chongqing Medical University (project no. HLYB2024–04). The funder had no role in the study design, data collection, statistical analysis, or manuscript writing.

Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
The study was approved by the Ethics Committee of the First Affiliated Hospital of Chongqing Medical University. Written informed consent was obtained from respiratory and critical care medicine inpatients. Ethics Number:202422401.

Consent for publication
Written informed consent from respiratory and critical care medicine inpatients was obtained for publication.

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