RESEARCH PAPER

Serum Sclerostin Levels and Their Association with Body Composition, Lung Function, and Exacerbations in COPD Patients

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Abstract

Background: Chronic obstructive pulmonary disease is associated with systemic manifestations, including skeletal muscle loss, altered body composition, and impaired bone metabolism.

Objective: To determine serum sclerostin levels and assess their association with body composition, lung function, and exacerbations among patients with COPD.

Methods: This analytical cross-sectional study was conducted at Naseer Teaching Hospital Peshawar from May 2024 to May 2025 included 145 clinically stable patients with COPD. Demographic and clinical characteristics, smoking history, exacerbations during the preceding 12 months, and hospitalizations were recorded.

Results: The mean age of participants was 62.7 ± 8.9 years, and 108 (74.5%) were male. The mean serum sclerostin level was 41.8 ± 13.7 pmol/L. Sclerostin levels decreased significantly across mild, moderate, severe, and very severe COPD groups from 52.6 ± 11.4 to 30.8 ± 10.3 pmol/L ($p < 0.001$). Patients with reduced fat-free mass index had lower sclerostin levels than those with preserved fat-free mass index (34.7 ± 11.2 vs 46.8 ± 12.9 pmol/L, $p < 0.001$). Frequent exacerbators also had lower levels than non-frequent exacerbators (33.9 ± 10.8 vs 47.2 ± 13.1 pmol/L, $p < 0.001$).

Conclusion: Lower serum sclerostin levels were associated with reduced lean body mass, poorer pulmonary function, greater COPD severity, and increased exacerbation burden. Serum sclerostin may serve as a potential biomarker of systemic musculoskeletal involvement and adverse clinical outcomes in COPD.

Keywords: Chronic obstructive pulmonary disease; sclerostin; body composition; lung function; exacerbations

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Introduction

Chronic obstructive pulmonary disease (COPD) is a heterogeneous lung disease with chronic respiratory symptoms and airflow limitation due to abnormalities of the airways and alveoli. COPD has historically been thought of as a pulmonary disease, but it now has been identified as a systemic disease with associated skeletal muscle dysfunction, a change in body composition, osteoporosis, cardiovascular disease, metabolic abnormalities, and decreased functional capacity [1]. In some cases these extrapulmonary manifestations are also severe enough to cause exercise intolerance, decreased quality of life, frequent hospitalizations and death, and in some patients they are not related to the extent of airflow obstruction. Body composition changes are common in COPD and can involve sarcopenia, a decrease in fat-free mass, central obesity, and weight loss, as well as sarcopenic obesity [2]. BMI may not be a sensitive indicator of actual skeletal muscle depletion as patients with normal or elevated BMI can have a significant loss of lean mass. Sarcopenia has been linked to decreased pulmonary function, increased airflow limitation, reduced exercise capacity, prolonged hospital stay, and mortality, among COPD patients [2,3]. The results of this study indicate that there is a need for greater research into the biological mechanisms that link lung dysfunction to musculoskeletal deterioration [4].

The association of skeletal muscle loss with poor bone health in COPD is probably multifactorial. Chronic systemic inflammation, physical inactivity, smoking, hypoxemia, nutritional deficiencies, aging, corticosteroid use and recurrent exacerbations can all contribute to the dysfunction of muscle, bone, and pulmonary function. There is growing evidence that the bone-skeletal muscle relationship is also mediated by biologically active molecules called "osteokines" and "myokines [5]. The muscle-bone cross-talk might be related to the parallel

progression of sarcopenia and osteoporosis and might serve as markers of systemic disease activity in COPD [4,5]. The SOST gene encodes the glycoprotein sclerostin, which is mainly secreted by osteocytes. It blocks the canonical Wnt/β-catenin signaling pathway by inhibiting the interaction of low-density lipoprotein receptor-related proteins 5 and 6 with Wnt proteins, which helps to prevent osteoblast differentiation and bone formation [6]. But sclerostin is now known to have more functions than just as a marker of skeletal metabolism. It is suggested that its circulating level corresponds to muscle mass, adiposity, physical activity, metabolic status, and the communication between bone and skeletal muscle. The properties of serum sclerostin make it a potentially relevant biomarker in COPD, where abnormalities of bone, muscle, and body composition are common [7].

Recently, there has been interest in the relationship of sclerostin to outcomes in the lungs. Serum sclerostin levels correlated with several measurements of body composition and lung function in 139 stable COPD outpatients. Patients with lower concentrations of sclerostin had worse pulmonary function, lower fat-free mass index, higher exacerbation and hospitalization rates, and lower exercise capacity. Decreased serum sclerostin also was found to be a possible predictor of subsequent exacerbations of COPD [8]. The present results indicate that sclerostin in the circulation may be a result of interactions between skeletal integrity, muscle loss, functional deficits, and severity of respiratory disease. However, there is still limited evidence available, and the relationship of these factors may be age- and sex dependent, as well as affected by renal function, physical activity, corticosteroid use, bone mineral density, and disease severity [9]. Acute exacerbations are a crucial component of the natural history of COPD as they exacerbate symptoms, speed up functional decline and result in greater use of health care services and put patients at risk of further hospitalisation and mortality [10]. Current clinical markers are not sufficient to explain why some patients have more exacerbations than others with a similar level of airflow limitation. Thus, biomarkers which reflect both systemic alterations of muscle, fat and bone and pulmonary dysfunction would be useful for clinical phenotyping and risk stratification [11].

Objective

To measure serum sclerostin levels and investigate the relationships between sclerostin levels, exacerbation and body composition in COPD patients.

Methodology

This analytical cross-sectional study was conducted at Naseer Teaching Hospital Peshawar from May 2024 to May 2025. The number of patients who participated in the study was 145, determined by a non-probability consecutive sampling.The study revealed a total number of 145 patients with confirmed diagnosis of chronic obstructive pulmonary disease, which were enrolled using non-probability consecutive sampling technique. Those who attended the pulmonary out-patient department or were admitted for routine assessment were screened based on pre-defined inclusion and exclusion criteria. The patients were included if they were 40 years or older with a diagnosis of COPD confirmed by post-bronchodilator spirometry with FEV_1/FVC ratio less than 0.70, regardless of gender. Patients were included if there had been no acute exacerbation of the disease in the last four weeks. Patients who had bronchial asthma, active pulmonary tuberculosis, interstitial lung disease, bronchiectasis, lung malignancy, acute respiratory infection, chronic kidney disease, thyroid or parathyroid disorders, known metabolic bone disease, or were currently taking anti-sclerostin therapy were excluded. There were also exclusion criteria for patients taking bisphosphonates, denosumab, long-term systemic corticosteroids, or other drugs significantly affecting bone metabolism.

Data Collection Procedure

Each participant gave written informed consent after approval by the institutional ethical review committee. A structured data collection form was used to obtain the demographic and clinical data. Data recorded comprised age, gender, smoking status, number of pack-years, COPD duration, presence of comorbidities, current medications, oxygen use, exacerbation number, number of visits to the emergency department and hospital admissions in the previous 12 months. COPD exacerbation was defined as an acute deterioration of respiratory symptoms beyond normal diurnal fluctuations that needed antibiotics, systemic corticosteroids, an emergency department visit, or hospitalisation. Patients who reported having two or more moderate exacerbations or at least one exacerbation that was hospitalized in the last 12 months were classified as frequent exacerbators. The digital scale was used for measuring body weight, and a stadiometer was used for measuring height, which was mounted on the wall. BMI (kg/m2) was computed by dividing weight (kg) by height (m2). Body composition was determined by bioelectrical impedance analysis (BIA) using a standard device (BTA 200). Body fat percentage, fat mass, fat-free mass, skeletal muscle mass, visceral fat level and total body water were assessed. The fat-free mass index was determined as the fat-free mass (kg) divided by height (m2). Participants were measured while wearing light clothing and were barefoot. Participants were instructed not to eat too much before the test, not to drink too much, and not to drink alcohol or exercise before the test.

Pulmonary Function Assessment

All pulmonary function tests were measured by a calibrated spirometer with trained staff. Spirometry

was done before and 15 minutes after giving an inhaled short-acting bronchodilator. Post-bronchodilator FEV1, FVC, FEV1/FVC, FEV1% predicted and FVC% predicted were obtained. Airflow Limitation was classified as mild, moderate, severe and very severe based on the percentage predicted FEV1 after bronchodilation. Three or more technically acceptable spirometric manoeuvres were obtained and the technically best value(s) were used for analysis.

Serum Sclerostin Measurement

Fasting venous blood was drawn from each subject aseptically in about 5 mL. The sample was left to clot and then centrifuged at around 3000 revolutions per minute for 10 minutes. The separated serum was aliquoted and stored at −80°C for biochemical analysis. Serum sclerostin concentration was assessed by an enzyme-linked immunosorbent assay kit (ELISA) according to the manufacturer's instructions. Each sample was analysed twice, and the average value used in the final analysis. Kit manufacturer, kit catalogue no., detection range, intra-assay and inter-assay coefficient of variations were recorded. Patients having COPD served as the primary outcome, and serum sclerostin concentration was measured in these patients. Secondary outcomes were its association with body mass index, fat mass, fat-free mass, skeletal muscle mass, fat-free mass index, post-bronchodilator FEV_1, FVC, FEV_1/FVC ratio, COPD severity and exacerbation frequency in the preceding 12 months.

Statistical Analysis

IBM SPSS Statistics version 26 was used for entering and analysing the data. The Shapiro–Wilk test was used to test continuous variables for normality. Variables with normal distribution were presented as mean ± standard deviation and those that did not follow a normal distribution were reported as median and interquartile range. Categorical variables were summarized in terms of frequencies and percent. A p value of < 0.05 with two tails was deemed statistically significant.

Results

The study included 145 patients with COPD, with a mean age of 62.7 ± 8.9 years. Most participants were male (74.5%), while 25.5% were female. Former smokers constituted the largest group (52.4%), followed by current smokers (36.6%) and never smokers (11.0%), with a mean smoking exposure of 38.9 ± 18.7 pack-years. The mean duration of COPD was 7.3 ± 4.1 years. The mean body mass index was 24.6 ± 4.5 kg/m², while mean fat mass, fat-free mass, skeletal muscle mass, and fat-free mass index were 20.8 ± 7.4 kg, 46.2 ± 8.8 kg, 24.9 ± 5.3 kg, and 16.8 ± 2.6 kg/m², respectively. Mean post-bronchodilator FEV_1 was 51.9 ± 18.6% predicted, FVC was 69.4 ± 17.2% predicted, and the FEV_1/FVC ratio was 0.54 ± 0.09.

Table 1. Baseline demographic and clinical characteristics of COPD patients (n = 145)

Variable	Category	n (%) / Mean ± SD
Age (years)	Overall	62.7 ± 8.9
Gender	Male	108 (74.5)
	Female	37 (25.5)
Smoking status	Current smoker	53 (36.6)
	Former smoker	76 (52.4)
	Never smoker	16 (11.0)
Smoking exposure (pack-years)	Overall	38.9 ± 18.7
Duration of COPD (years)	Overall	7.3 ± 4.1
Body mass index (kg/m²)	Overall	24.6 ± 4.5
Fat mass (kg)	Overall	20.8 ± 7.4
Fat-free mass (kg)	Overall	46.2 ± 8.8
Skeletal muscle mass (kg)	Overall	24.9 ± 5.3
Fat-free mass index (kg/m²)	Overall	16.8 ± 2.6
Post-bronchodilator FEV_1 (% predicted)	Overall	51.9 ± 18.6
Post-bronchodilator FVC (% predicted)	Overall	69.4 ± 17.2
FEV_1/FVC ratio	Overall	0.54 ± 0.09
Exacerbations during previous year	Overall	1.7 ± 1.3
Frequent exacerbator	Yes	59 (40.7)

	No	86 (59.3)
Serum sclerostin (pmol/L)	Overall	41.8 ± 13.7

Serum sclerostin levels decreased significantly with increasing COPD severity, from 52.6 ± 11.4 pmol/L in mild disease to 45.1 ± 12.0 pmol/L in moderate, 37.9 ± 11.8 pmol/L in severe, and 30.8 ± 10.3 pmol/L in very severe COPD ($F = 16.82$, $p < 0.001$). Patients with reduced fat-free mass index had significantly lower sclerostin levels than those with preserved fat-free mass index (34.7 ± 11.2 vs 46.8 ± 12.9 pmol/L; $t = 5.77$, $p < 0.001$). Frequent exacerbators also had lower levels than non-frequent exacerbators (33.9 ± 10.8 vs 47.2 ± 13.1 pmol/L; $t = 6.42$, $p < 0.001$).

Table 2. Serum sclerostin levels according to clinical characteristics

Variable	Category	n	Serum sclerostin (pmol/L), Mean ± SD	Test statistic	p-value
COPD severity	Mild	24	52.6 ± 11.4	F = 16.82	<0.001
	Moderate	51	45.1 ± 12.0		
	Severe	46	37.9 ± 11.8		
	Very severe	24	30.8 ± 10.3		
Fat-free mass index	Reduced	58	34.7 ± 11.2	t = 5.77	<0.001
	Preserved	87	46.8 ± 12.9		
Frequent exacerbator	Yes	59	33.9 ± 10.8	t = 6.42	<0.001
	No	86	47.2 ± 13.1		
Hospitalization during previous year	Yes	48	32.8 ± 10.7	t = 6.22	<0.001
	No	97	46.3 ± 13.0		
Long-term oxygen therapy	Yes	31	31.6 ± 9.8	t = 5.42	<0.001
	No	114	44.6 ± 13.5		

Serum sclerostin showed significant positive correlations with fat-free mass ($r = 0.417$), skeletal muscle mass ($r = 0.452$), fat-free mass index ($r = 0.486$), FEV_1 percentage predicted ($r = 0.548$), FVC percentage predicted ($r = 0.391$), and FEV_1/FVC ratio ($r = 0.436$), with all p-values < 0.001. In contrast, sclerostin was inversely correlated with COPD duration ($r = -0.276$, $p = 0.001$), smoking exposure ($r = -0.231$, $p = 0.005$), number of exacerbations ($r = -0.512$, $p < 0.001$), and hospital admissions ($r = -0.461$, $p < 0.001$). No significant association was observed with body mass index ($r = 0.124$, $p = 0.137$) or fat mass ($r = 0.098$, $p = 0.241$).

Table 3. Correlation of serum sclerostin with body composition, lung function, and exacerbation-related variables

Variable	Correlation coefficient (r)	p-value
Body mass index	0.124	0.137
Fat mass	0.098	0.241
Fat-free mass	0.417	<0.001
Skeletal muscle mass	0.452	<0.001
Fat-free mass index	0.486	<0.001
FEV_1 (% predicted)	0.548	<0.001
FVC (% predicted)	0.391	<0.001
FEV_1/FVC ratio	0.436	<0.001
COPD duration	−0.276	0.001

Smoking exposure	−0.231	0.005
Number of exacerbations	−0.512	<0.001
Number of hospital admissions	−0.461	<0.001

Each 1 kg/m² increase in fat-free mass index was associated with a 1.31 pmol/L increase in sclerostin (95% CI: 0.63–1.99, p < 0.001), while each 1% increase in FEV_1 predicted was associated with a 0.24 pmol/L increase (95% CI: 0.14–0.34, p < 0.001). Conversely, each additional exacerbation was associated with a 2.67 pmol/L reduction in serum sclerostin (95% CI: −3.86 to −1.48, p < 0.001). Age, gender, smoking exposure, body mass index, and COPD duration were not independently significant.

Table 4. Multivariable linear regression analysis of factors associated with serum sclerostin levels

Variable	Unstandardized coefficient (B)	Standardized β	95% CI for B	p-value
Age (years)	−0.09	−0.06	−0.28 to 0.10	0.342
Male gender	1.72	0.05	−2.31 to 5.75	0.400
Smoking exposure (pack-years)	−0.06	−0.08	−0.15 to 0.03	0.176
Body mass index (kg/m²)	0.18	0.06	−0.19 to 0.55	0.338
Fat-free mass index (kg/m²)	1.31	0.25	0.63 to 1.99	<0.001
FEV_1 (% predicted)	0.24	0.33	0.14 to 0.34	<0.001
COPD duration (years)	−0.22	−0.07	−0.61 to 0.17	0.268
Number of exacerbations	−2.67	−0.29	−3.86 to −1.48	<0.001

Discussion

This study examined serum sclerostin concentrations and their correlations with body composition, pulmonary function and exacerbation burden in 145 patients with stable COPD. The main conclusion was that sclerostin levels in the serum decreased as airflow limitation worsened. Patients with low FFM index, frequent exacerbations, previous hospitalization and long term oxygen use also had lower concentrations of sclerostin. Moreover, sclerostin levels were positively associated with measures of lean body mass and spirometry, and negatively associated with exacerbation frequency, hospital admissions, duration of COPD, and cumulative smoking exposure. In the current cohort, the mean serum sclerostin level was 41.8 ± 13.7 pmol/L, with patients having mild COPD exhibiting significantly higher concentrations compared to patients with very severe COPD, and serum sclerostin exhibiting a moderately strong positive correlation with FEV_1 % predicted [12]. The results indicate that lower sclerostin levels in blood are correlated with the worsening of pulmonary function. Previous studies of stable COPD patients also showed that sclerostin levels in serum were related to lung function and that decreased sclerostin levels were seen in patients with more severe respiratory failure [1]. The exact biological explanation is not known, but severe COPD is associated with physical inactivity, chronic hypoxia, systemic inflammation, corticosteroid use and altered mechanical loading, which may affect osteocyte activity and Wnt signalling [13,14].

Fat-free mass, skeletal muscle mass and fat-free mass index were also positively correlated with serum sclerostin. Concentrations were significantly lower in patients with low FFMI than in patients with normal FFMI. This further suggests that sclerostin may be a sign of bone–muscle interaction, not just bone metabolism. Loss of fat-free mass is associated with impaired lung function, limited physical capacity, hospitalisation and poor prognosis

in previous COPD studies [15]. Longitudinal data further suggest that patients with COPD may lose fat-free mass, which is especially the case when they have a history of hospitalization [4]. The positive correlation between sclerostin and lean mass in the present study is in line with the study of older individuals, which demonstrated that higher levels of sclerostin were related to decreased risk of sarcopenia, low muscle mass and muscle weakness [16]. But the tie with that's not yet finalized. Other studies have found an inverse relationship between sclerostin (after adjustment for bone mass and fat mass) and skeletal muscle mass [17]. The seemingly contradictory results suggest that serum sclerostin might have different effects based on age, sex, renal function, physical activity, skeletal loading, bone turnover, and disease. It should, therefore, not be viewed as a direct measure of muscle mass at this point, but with these confounding factors [18].

Body mass index and fat mass were however not associated with serum sclerostin. The difference is important clinically because BMI doesn't differentiate between fat tissue and skeletal muscle. This means that the patient can consequently have a normal BMI or even high BMI despite significant muscle loss. Other studies have also noted that having a low fat-free mass index can be seen in all BMI classifications and can detect functional impairment not detected by body weight [19]. The results corroborated the use of direct body composition assessment in addition to body mass index (BMI) in the assessment of systemic manifestations of COPD. The serum level of sclerostin was significantly lower in the frequent exacerbators than the non-frequent exacerbators, and there was a strong inverse correlation between exacerbation frequency and sclerostin. An adjusted analysis revealed that every 5 pmol/L rise in serum sclerostin was linked to a 22% decrease in the likelihood of being in the frequent-exacerbator group. This is consistent with earlier studies that low levels of sclerostin were associated with an increased risk of exacerbation of COPD and hospitalization [20]. Exacerbations can play a role in lowering sclerostin levels due to a decrease in activity, systemic inflammation, hypoxia, nutritional issues, and accelerated muscle and bone loss. On the other hand, low sclerostin can help determine patients with more advanced systemic dysfunction who are already more susceptible to exacerbations. The current study was observational in nature, so it is not possible to conclude as to the direction of this relationship. Results have several clinical implications. Measurement of sclerostin in serum along with spirometry and body composition may be useful in identifying COPD patients with more extensive systemic involvement and increased risk for exacerbation. Dietary assessment, resistance training, pulmonary rehab, bone health evaluation, smoking cessation, and increased monitoring may be helpful for these patients. Routine clinical use is, however, not recommended at present due to a lack of assay standardization, clinically relevant thresholds, biological variability, and renal and bone disease effects. The study was limited in that it was cross-sectional and therefore was not representative of cause and effect. The incidence of exacerbations was assessed retrospectively but may have been influenced by recall or documentation bias. Body composition was also not assessed by using dual-energy X-ray absorptiometry, and bone mineral density, physical activity, vitamin D, parathyroid hormone, inflammatory markers and bone-turnover markers were not measured. Limitations of generalizability could be attributed to the one-centre context and the relatively small sample size. The study was therefore limited, but also assessed the serum level of sclerostin, body composition, spirometry, and clinically relevant exacerbation outcomes.

Conclusion

Reduced fat-free mass, less lung function, increasing COPD severity, and increased exacerbation and hospitalization rates were all correlated with lower levels of sclerostin. Fat-free mass index, FEV_1 percentage predicted, and exacerbation burden were still independently correlated with serum sclerostin. Based on these findings, serum sclerostin could be a useful systemic musculoskeletal biomarker and a predictor of adverse clinical outcomes in COPD.

References

1. Amado CA, García-Unzueta M, Agüero J, Martín-Audera P, Fueyo P, Lavín BA, Guerra AR, Muñoz P, Tello S, Berja A, Casanova C. Associations of serum sclerostin levels with body composition, pulmonary function, and exacerbations in COPD patients. Pulmonology. 2024 Nov-Dec;30(6):512-521. doi: 10.1016/j.pulmoe.2022.06.003. Epub 2022 Aug 11. PMID: 35963832.
2. Cuttitta, G., Ferraro, M., Cibella, F., Alfano, P., Bucchieri, S., Patti, A. M., Muratori, R., Pace, E., & Bruno, A. (2023). Relationship among Body Composition, Adipocytokines, and Irisin on Exercise Capacity and Quality of Life in COPD: A Pilot Study. *Biomolecules*, *13*(1), 48. https://doi.org/10.3390/biom13010048
3. Hu C, Song B, Liu X, Sun L, Li M, He X. The Association Between COPD, Acute Exacerbations of COPD, and Survival in COPD, with Fat-Free Body Mass Index: A Systematic Review and Meta-Analysis. Int J Chron Obstruct Pulmon Dis. 2025 Jul 25;20:2589-2600. doi: 10.2147/COPD.S526194. PMID: 40734724; PMCID: PMC12306560.
4. Sioutas, A., & Persson, H. L. (2026). Serum Vitamin D Levels, Systemic Inflammation,

and Exacerbation Among Patients with COPD GOLD Group E. *Biomedicines*, *14*(4), 833. https://doi.org/10.3390/biomedicines14040833

5. Mjid M, Snène H, Hedhli A, Cheikh Rouhou S, Toujani S, Dhahri B. COPD patients' body composition and its impact on lung function. Tunis Med. 2021 Feb;99(2):285-290. English. PMID: 33899200; PMCID: PMC8636975.
6. Wang H, Ge C, Zhang Z, Geng Z, Zhang L. Effects of physical activity and sedentary behavior on serum vitamin D in patients with chronic obstructive pulmonary disease. Adv Clin Exp Med. 2024;33:1329-1341.
7. Janssens W, Bouillon R, Claes B, Carremans C, Lehouck A, Buysschaert I, et al. Vitamin D deficiency is highly prevalent in COPD and correlates with variants in the vitamin D-binding gene. Thorax. 2010;65:215-220.
8. Persson LJ, Aanerud M, Hiemstra PS, Hardie JA, Bakke PS, Eagan TM. Chronic obstructive pulmonary disease is associated with low levels of vitamin D. PLoS One. 2012;7.
9. Måhlin C, von Sydow H, Osmancevic A, Emtner M, Grönberg AM, Larsson S, et al. Vitamin D status and dietary intake in a Swedish COPD population. Clin Respir J. 2014;8:24-32.
10. Kentson M, Leanderson P, Jacobson P, Persson HL. The influence of disease severity and lifestyle factors on the peak annual 25(OH)D value of COPD patients. Int J Chron Obstruct Pulmon Dis. 2018;13:1389-1398.
11. Foong RE, Zosky GR. Vitamin D deficiency and the lung: disease initiator or disease modifier? Nutrients. 2013;5:2880-2900.
12. Kokturk N, Baha A, Oh YM, Ju YJ, Jones PW. Vitamin D deficiency: what does it mean for chronic obstructive pulmonary disease? A comprehensive review for pulmonologists. Clin Respir J. 2018;12:382-397.
13. Tang W, Rong Y, Zhang H, Zhan Z, Yuan L, Ning Y, et al. The correlation between a Th1/Th2 cytokine imbalance and vitamin D level in patients with early chronic obstructive pulmonary disease based on screening results. Front Physiol. 2023;14:1032786.
14. Black PN, Scragg R. Relationship between serum 25-hydroxyvitamin D and pulmonary function in the Third National Health and Nutrition Examination Survey. Chest. 2005;128:3792-3798.
15. Burkes RM, Ceppe AS, Doerschuk CM, Couper D, Hoffman EA, Comellas AP, et al. Associations among 25-hydroxyvitamin D levels, lung function, and exacerbation outcomes in COPD: an analysis of the SPIROMICS cohort. Chest. 2020;157:856-865.
16. Ghosh AJ, Moll M, Hayden LP, Bon J, Regan E, Hersh CP, et al. Vitamin D deficiency is associated with respiratory symptoms and airway wall thickening in smokers with and without COPD: a prospective cohort study. BMC Pulm Med. 2020;20:123.
17. Lee CY, Shin SH, Choi HS, Im Y, Kim BG, Song JY, et al. Association between vitamin D level and respiratory symptoms in patients with stable chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis. 2022;17:579-590.
18. Carson EL, Pourshahidi LK, Madigan SM, Baldrick FR, Kelly MG, Laird E, et al. Vitamin D status is associated with muscle strength and quality of life in patients with COPD: a seasonal prospective observational study. Int J Chron Obstruct Pulmon Dis. 2018;13:2613-2622.
19. Kunisaki KM, Niewoehner DE, Connett JE; COPD Clinical Research Network. Vitamin D levels and risk of acute exacerbations of chronic obstructive pulmonary disease: a prospective cohort study. Am J Respir Crit Care Med. 2012;185:286-290.
20. Ferrari R, Caram LMO, Tanni SE, Godoy I, Rupp de Paiva SA. The relationship between vitamin D status and exacerbation in COPD patients: a literature review. Respir Med. 2018;139:34-38.