



Older Age and Low Body Mass Index as Predictors of Sarcopenia in Chronic Obstructive Pulmonary Disease: A Cross-Sectional Study

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Abstract

Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disorder frequently accompanied by systemic complications, including sarcopenia, which may reduce physical capacity and worsen clinical outcomes. This study aimed to determine the prevalence of sarcopenia and identify its associated predictors among patients with stable COPD. A cross-sectional study was conducted among 67 patients with stable COPD who attended the Pulmonology Outpatient Clinic at Universitas Sumatera Utara Hospital. Muscle mass was assessed using bioelectrical impedance analysis and expressed as the skeletal muscle index, while muscle strength was measured using a handgrip strength test. Descriptive, bivariate, and receiver operating characteristic (ROC) analyses were performed. The results showed that 55.2% of participants had reduced muscle strength, 38.8% had low muscle mass, and 29.9% met the diagnostic criteria for sarcopenia. Older age and lower body mass index (BMI) were significantly associated with sarcopenia. An age threshold of >66 years predicted sarcopenia with 75.0% sensitivity and 66.0% specificity, whereas a BMI threshold of <23 kg/m² demonstrated 76.6% sensitivity and 85.0% specificity. In conclusion, sarcopenia was prevalent even among clinically stable COPD patients. Routine assessment of age, BMI, muscle mass, and handgrip strength may support early detection and facilitate timely nutritional and rehabilitative interventions to prevent functional decline and improve patient outcomes.

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a chronic and progressive disease (Polosukhin et al., 2021). COPD arises from the interaction of multiple risk factors that trigger immune responses and sustain chronic inflammation. As the disease progresses, irreversible airflow limitation develops due to structural changes in the small airways, including airway remodeling and subepithelial fibrosis (Jones et al., 2016). This remodeling process, characterized by bronchial wall thickening and airway narrowing, significantly impairs respiratory function and is considered irreversible (Wang et al., 2018).

COPD is responsible for approximately 3.23 million deaths, 90% of which occur in low- and middle-income countries (LMICs) (Varmaghani et al., 2019). It also ranks as the seventh leading cause of global disease burden based on disability-adjusted life years (DALYs) (Hurst & Siddharthan, 2020). COPD is frequently associated with multiple comorbidities, including sarcopenia and impaired musculoskeletal health. Recently, sarcopenia has emerged as a significant comorbidity among patients with COPD (Rao et al., 2021). Several reports have demonstrated a considerable prevalence of sarcopenia in this population, attributed to aging, persistent inflammation, smoking, high symptom burden, and cardiovascular comorbidities

(Benz, Trajanoska, et al., 2019). These factors contribute to a pro-inflammatory environment that promotes muscle wasting. In the general population, the prevalence of sarcopenia ranges from 4.4% to 27.5% and increases significantly among individuals with chronic diseases such as COPD (He et al., 2023). The Rotterdam Study demonstrated that COPD prevalence was more than 20% higher among individuals with sarcopenia (Trajanoska et al., 2018). Conversely, the prevalence of sarcopenia increases with advancing COPD severity, particularly among patients classified as GOLD stages 3–4 (van Bakel et al., 2021).

Therefore, preventing sarcopenia in patients with COPD is crucial because it may reduce comorbidity burdens and improve disease management (Zhao, Y., et al., 2024). Sarcopenia is associated with increased susceptibility to recurrent infections, longer hospital stays, frequent exacerbations, and higher disease-specific mortality (Perrot et al., 2020; Zhao, X., et al., 2023; de Araújo et al., 2021). Therefore, this study aims to investigate the prevalence of sarcopenia among stable patients with COPD with diverse clinical profiles and body compositions, as well as to identify and predict variables associated with this condition. Early recognition of sarcopenia can facilitate comprehensive and targeted interventions to improve COPD management and ultimately enhance quality of life in this specific population.

Another important challenge is that reliance on body mass index (BMI) alone may obscure underlying changes in body composition. Patients with COPD may have a BMI within the normal range while simultaneously experiencing reduced skeletal muscle mass and muscle strength, a phenotype that may be described as sarcopenia with normal body weight. BMI measures total body weight relative to height but cannot distinguish between muscle tissue and adipose tissue. Consequently, patients who appear stable or adequately nourished may not undergo further assessment and may remain undiagnosed until functional decline becomes evident. Bioelectrical impedance analysis and handgrip dynamometry provide relatively accessible methods for evaluating muscle mass and strength in outpatient settings. Combining these measurements may therefore provide more clinically meaningful information than anthropometric evaluation alone, particularly in settings where dual-energy X-ray absorptiometry and comprehensive physical performance testing are not routinely available.

Despite the growing body of research, several gaps remain. Most published studies have been conducted in Europe, East Asia, or other non-Indonesian populations, whereas evidence from Indonesia has often focused on older community-dwelling populations, rehabilitation settings, or general COPD characteristics rather than estimating sarcopenia prevalence and its predictors among stable COPD outpatients. Previous studies have also frequently emphasized patients with advanced COPD, severe symptom burdens, or acute exacerbations, potentially reinforcing the assumption that sarcopenia primarily occurs in advanced disease stages. Furthermore, comparatively few studies have evaluated the predictive ability of simple clinical characteristics, such as age and BMI, by establishing locally relevant cutoff values through receiver operating characteristic (ROC) curve analysis. These limitations restrict clinicians' ability to identify stable patients who require further assessment before overt disability, frequent exacerbations, or severe malnutrition develops.

Addressing these gaps is urgent because stable clinical status does not necessarily indicate preserved musculoskeletal health. Detecting sarcopenia during routine outpatient care would enable earlier nutritional interventions, resistance training, pulmonary rehabilitation, and management of modifiable contributors to muscle loss. The novelty of the present study

lies in its evaluation of sarcopenia among stable COPD patients in Medan, Indonesia, using a pragmatic combination of skeletal muscle index obtained through bioelectrical impedance analysis and muscle strength assessed through handgrip testing. It additionally examines the ability of age and BMI to predict sarcopenia and determines clinically interpretable thresholds through ROC curve analysis. By focusing on patients with diverse clinical profiles, including those with relatively stable symptoms and limited recent exacerbation histories, this study evaluates whether muscle dysfunction may already be present before COPD reaches an advanced clinical stage.

Accordingly, this study aims to determine the prevalence of sarcopenia among stable COPD patients and investigate demographic, clinical, and body composition factors associated with the condition, with particular attention to age and BMI as practical predictors. Its scientific contribution is expected to enrich the limited evidence regarding sarcopenia in Indonesian COPD populations and clarify the relevance of muscle assessment among clinically stable patients. From a clinical perspective, the findings may support a feasible risk-stratification approach for identifying patients who should undergo further nutritional and functional evaluations. The study may also assist pulmonologists and multidisciplinary healthcare teams in integrating sarcopenia screening into routine COPD management, facilitating earlier personalized interventions and providing a foundation for longitudinal and multicenter research examining the effects of sarcopenia on exacerbations, hospitalization, functional decline, quality of life, and mortality.

METHOD

Patient selection and inclusion criteria

This cross-sectional study involved stable COPD patients attending the Outpatient Clinic of the Department of Pulmonology at Universitas Sumatera Utara Hospital, Medan, Indonesia, between October and December 2024. The inclusion criteria were: (1) confirmed COPD diagnosed based on spirometry results documented in the hospital medical records; (2) a stable clinical condition without acute exacerbations; and (3) ongoing treatment with good adherence. Patients were enrolled after providing written informed consent. The exclusion criteria included a history of cardiothoracic surgery or marked restrictive lung abnormalities.

Sarcopenia measurement

Sarcopenia was assessed by using two parameters, muscle strength and physical performance. This was based on the criteria enacted by the guidelines of European Working Group on Sarcopenia in Older People (EWGSOP) and the Asian Working Group for Sarcopenia (AWGS). According to EWGSOP, The presence of sarcopenia is diagnosed with low muscle mass along with either low muscle strength or low physical performance. AWGS similarly identifies three indicators—impaired muscle mass, decreased muscle strength, and abnormal physical performance test results—and considers sarcopenia to be present when at least two of these criteria are met.¹⁵ In this study, sarcopenia was established based on two parameters: muscle mass (measured by using skeletal muscle index/SMI) and muscle strength (formulated based on handgrip test results). The presence of both reduced muscle mass and strength was considered sufficient to establish sarcopenia in this population.

Statistical analysis

Sarcopenia prevalence and other factors were analyzed descriptively (univariate analysis), including demographic characteristics (such as age, sex, and comorbidities), muscle mass, and handgrip strenght test result. Sarcopenia prevalence was determined based on the proportion of patients fulfilled the criteria for both reduced SMI and muscle strength.

Ethical clearance

This study received ethical approval from the local Medical Research Ethics Committee of the Faculty of Medicine, Universitas Sumatera Utara, Medan, Indonesia (Reference No: 256/KEPK/USU/2025).

RESULTS AND DISCUSSION

This study involved 67 participants who were diagnosed with stable COPD, characterised by the predominance of older individuals (68.7%) and males (80.6%). Smoking emerged as a significant risk factor among COPD patients (52.2% identified as former smokers, while 28.4% as active smokers). Comorbidities were confirmed in 53.7% of study participants, with cardiovascular comorbidities accounting for 31.3%, including chronic hypertension, coronary artery disease (CAD), and heart failure. Diabetes mellitus type 2 (DMT2) was demonstrated among 9.0% of participants. Post-tuberculosis and lung tumors contribute to 3% of comorbidities.

The muscle mass and fat mass of the study participants was determined based on specialised bioelectrical impedance analysis (BIA) results (Table 1). The average body weight of participants in this study was 62.25 ± 11.43 kg, and their average height was 161.50 ± 6.73 cm. The average BMI was 23.85 ± 4.17 kg/m², indicating that most study participants had a good nutritional status. However, further body composition analysis revealed that the average muscle mass was only 18.45 ± 3.53 kg, or $29.90 \pm 4.19\%$ of total body weight. This indicates a tendency toward reduced muscle mass in the COPD population, despite the average fat mass remaining within the normal range (16.94 ± 6.11 kg or $26.59 \pm 6.63\%$). Body composition data are presented as mean values, as several indicators lack established cut-off points.

Table 1. Body composition indicator.

Characteristics	Mean $\pm$ SD
Body weight (kg)	62.25 ± 11.43
Height (kg)	161.50 ± 6.73
Body mass index (kg/m ²)	23.85 ± 4.17
Muscle mass (kg)	18.45 ± 3.53
Muscle mass (%)	29.90 ± 4.19
Fat mass (kg)	16.94 ± 6.11
Fat mass (%)	26.59 ± 6.63

The study results demonstrated that more than 50% of the participants had low muscle strength, 55.2% (Table 3). Meanwhile, muscle mass measurement using SMI indicated that 38.8% of patients had low muscle mass, while the remaining 61.2% were within the normal range. SMI is used as an indicator of muscle mass based on the sarcopenia guidelines issued by the EWGSOP. According to the EWGSOP criteria, 29.9% of patients were classified as

having sarcopenia, while the remaining 70.1% were not categorized as sarcopenic. Age and body mass index were associated with sarcopenia incidence in the study population (Table 2). Age older than 66 years old associated with higher incidence of sarcopenia with sensitivity and specificity 75.0% and 66.0%, respectively (AUC 0.713, 95% CI 0.583-0.844; p 0.006). Meanwhile, BMI below 23 kg/m² predicts the optimal incidence of sarcopenia with sensitivity 76.6% and specificity 85.0% (AUC0.829, 95% CI 0.731-0.927; p 0.000).

Table 2. Bivariate analysis of several factors associated with sarcopenia.

Variables	Sarcopenia N (%)		p-value	OR 95% CI
	Yes	No		
Age (Years)				
< 60	2 (9.5)	19 (90.5)	0.014*	0.164 (0.034-0.789)
≥ 60	18 (39.1)	28 (60.9)		
Gender				
Male	19 (35.2)	35 (64.8)	0.052	6.514 (0.786-54.004)
Female	1 (7.7)	12 (92.3)		
Body Mass Index				
Under- to normoweight	17 (56.7)	13 (43.4)	0.000*	14.821 (3.714-59.135)
Over- to Obese	3 (8.1)	34 (91.9)		
GOLD Classification				
GOLD 1-2	13 (31.0)	29 (69.0)	0.798	1.153 (0.387-3.432)
GOLD 3-4	7 (28.0)	18 (72.0)		
mMRC Classification				
mMRC 0-1	6 (28.6)	15 (71.4)	0.877	0.914 (0.294-2.848)
mMRC 2-3	14 (30.4)	32 (69.6)		
Exacerbation (/year)				
No	14 (36.8)	24 (63.2)	0.152	2.236 (0.734-6.815)
Yes	6 (20.7)	23 (79.3)		

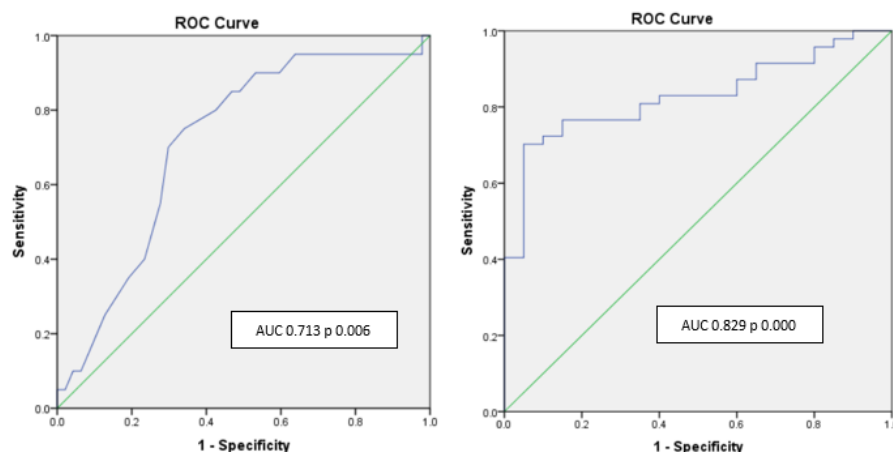


Figure 1. Receiving Operating Curve (ROC) analysis of age (left) and body mass index/BMI (right) against sarcopenia prevalence in the study population.

This research investigated the prevalence of sarcopenia and its associated components—muscle strength and SMI among stable COPD patients. The study findings revealed that a significant proportion of patients exhibited reduced muscle strength (55.2%) and low skeletal

muscle mass (38.8%), resulting in an overall sarcopenia prevalence of 29.9%. These results are consistent with previous reports that highlight the high burden of sarcopenia among individuals with stable COPD (Sepúlveda-Loyola et al., 2020).

Meanwhile, muscle strength, as measured by the handgrip test, was more frequently impaired than muscle mass in the study. This finding becomes the evidence that muscle strength is often a more sensitive and earlier marker of sarcopenia than muscle mass itself. Moreover, the relatively higher proportion of low muscle strength compared to low muscle mass emphasizes the importance of including functional assessments, not just body composition, when evaluating sarcopenia in clinical settings (Ferrari et al., 2015; Vaes et al., 2021).

In addition, the proportion of individuals with sarcopenia in our study is 29.9%. In contrast, several studies confirmed a higher prevalence of sarcopenia among COPD individuals, although data variations exist depending on diagnostic criteria, measurement tools, and patient demographics. Previous studies have reported sarcopenia prevalence ranging from 7.8% to 35% in COPD patients, with higher rates observed in those with advanced disease, poor nutritional status, and reduced physical activity (Moreira et al., 2014). In Yunani, 24.6% of COPD patients were diagnosed with sarcopenia, while 27.5–50.25% of sarcopenic individuals were found among several studies conducted in Indonesia (Tsekoura et al., 2020; Ridwan et al., 2021; Khairani et al., 2013). In addition, the EWGSOP-based diagnostic approach employed in this study offers a practical and widely accepted method for identifying sarcopenia, mainly when physical performance assessment is not feasible (Petermann-Rocha et al., 2020; Escriche-Escuder et al., 2021).

The conventional hypothesis explaining sarcopenia was strongly correlated with a condition characterised by advanced COPD, such as high burden symptoms, dyspnea, or inflammatory cytokine associated with recurrent exacerbations (Benz, Wijnant, et al., 2022). Nevertheless, this recent study demonstrated that a significant proportion of sarcopenia can also occur among very stable COPD patients, as most of the involved participants had a GOLD classification of A-B, an mMRC classification of ≤ 2 , and no exacerbation history within the previous year. These findings noted several new paradigms against muscle dysfunction among COPD patients that this disease's natural history frequently involves systemic physiology in multifaceted pathways, including older age, nutritional status, physical inactivity, inflammatory conditions, chronic hypoxia conditions, and excessive oxidative stress (Supriya et al., 2021).

Although there was considerable prevalence of sarcopenia in the study, the average BMI of participants was within the normal to upper-normal range ($23.85 \pm 4.17 \text{ kg/m}^2$). Further analysis of body composition revealed a discordant finding of low skeletal muscle mass but a normal BMI, indicating a condition referred to as "sarcopenic normal-weight"—a state characterized by a normal BMI yet low muscle mass and function (Martínez-Luna et al., 2022). In further analysis, it was notable that under- and normoweight associated with higher incidence of sarcopenia. This condition commonly contributes to the underdiagnosis of sarcopenia in routine clinical care, particularly among normoweight individuals (De Lorenzo et al., 2022). The obesity paradox also explains the protective effect of adipose tissue, indirectly represented by a higher BMI than sarcopenic individuals (Bosello & Vanzo, 2021).

The implications of sarcopenia in COPD are clinically significant. Sarcopenic individuals often suffer from significantly poorer exercise tolerance, increased risk of exacerbations, more extended hospital stays, and reduced quality of life (Mollica et al., 2021; Lippi et al., 2022; Wu et al., 2023). Identifying patients with sarcopenia early allows clinicians to implement more comprehensive and targeted management, such as resistance as well as strength training, nutritional supplementation, and anti-inflammatory strategies, which may help prevent further decline and improve patient outcomes (van Bakel et al., 2021).

LIMITATION

Nevertheless, this study had some limitations, including study design (as cross-sectional study, this could hamper causal inferences). The absence of physical performance assessment would have allowed for a more comprehensive classification of sarcopenia severity.

CONCLUSION

This study concluded that sarcopenia was a common extrapulmonary complication among stable patients with chronic obstructive pulmonary disease (COPD), affecting 29.9% of the 67 participants. Reduced muscle strength was identified in 55.2% of patients, whereas 38.8% had low skeletal muscle mass, indicating that functional impairment may occur earlier or more frequently than measurable muscle loss. Older age and lower body mass index (BMI) were significant predictors of sarcopenia. An age above 66 years predicted sarcopenia with 75.0% sensitivity and 66.0% specificity, while a BMI below 23 kg/m² demonstrated stronger predictive performance, with 76.6% sensitivity and 85.0% specificity. These findings emphasize that sarcopenia can develop even among clinically stable COPD patients and those with an apparently normal BMI. Therefore, routine assessments combining BMI, bioelectrical impedance analysis, and handgrip strength measurement should be integrated into COPD outpatient care to facilitate early nutritional and rehabilitative interventions.

Future studies should employ prospective, multicenter, and longitudinal designs with larger and more diverse samples to validate the predictive thresholds identified in this study and clarify the temporal relationship between COPD and sarcopenia. Researchers should incorporate comprehensive physical performance assessments, such as gait speed, the five-times sit-to-stand test, the Short Physical Performance Battery, and the six-minute walk test, to classify sarcopenia severity according to established diagnostic guidelines. Additional variables, including dietary intake, inflammatory biomarkers, physical activity levels, corticosteroid exposure, smoking history, disease duration, pulmonary function, and exacerbation frequency, should also be investigated. Future interventional studies should evaluate whether nutritional supplementation, resistance exercise, and structured pulmonary rehabilitation can improve muscle mass, muscle strength, functional capacity, quality of life, hospitalization rates, and survival among COPD patients at risk of sarcopenia.

REFERENCES

Benz, E., Trajanoska, K., Lahousse, L., et al. (2019). Sarcopenia in COPD: A systematic review and meta-analysis. *European Respiratory Review*, 28(154).

- Benz, E., Wijnant, S. R. A., Trajanoska, K., et al. (2022). Sarcopenia, systemic immune-inflammation index and all-cause mortality in middle-aged and older people with COPD and asthma: A population-based study. *ERJ Open Research*, 8(1).
- Bosello, O., & Vanzo, A. (2021). Obesity paradox and aging. *Eating and Weight Disorders—Studies on Anorexia, Bulimia and Obesity*, 26(1), 27–35.
- de Araújo, B. E., Teixeira, P. P., Valduga, K., et al. (2021). Prevalence, associated factors, and prognostic value of sarcopenia in patients with acute exacerbated chronic obstructive pulmonary disease: A cohort study. *Clinical Nutrition ESPEN*, 42, 188–194.
- De Lorenzo, A., Pellegrini, M., Gualtieri, P., et al. (2022). The risk of sarcopenia among adults with normal-weight obesity in a nutritional management setting. *Nutrients*, 14(24), 5295.
- Escrache-Escuder, A., Fuentes-Abolafio, I. J., Roldán-Jiménez, C., et al. (2021). Effects of exercise on muscle mass, strength, and physical performance in older adults with sarcopenia: A systematic review and meta-analysis according to the EWGSOP criteria. *Experimental Gerontology*, 151, 111420.
- Ferrari, R., Caram, L. M. O., Faganello, M. M., et al. (2015). Relation between systemic inflammatory markers, peripheral muscle mass, and strength in limb muscles in stable COPD patients. *International Journal of Chronic Obstructive Pulmonary Disease*, 1553–1558.
- He, J., Li, H., Yao, J., et al. (2023). Prevalence of sarcopenia in patients with COPD through different musculature measurements: An updated meta-analysis and meta-regression. *Frontiers in Nutrition*, 10, 1137371.
- Hurst, J. R., & Siddharthan, T. (2020). Global burden of COPD: Prevalence, patterns, and trends. In *Handbook of global health* (pp. 1–20).
- Jones, R. L., Noble, P. B., Elliot, J. G., et al. (2016). Airway remodelling in COPD: It's not asthma! *Respirology*, 21(8), 1347–1356.
- Khairani, F., Kholis, F. N., & Ngestiningsih, D. (2013). *Hubungan antara skor COPD Assessment Test (CAT) dengan rasio FEV1/FVC pada pasien Penyakit Paru Obstruktif Kronik (PPOK) klinis: Studi kasus pada pasien di RSUP Dr. Kariadi Semarang*. Diponegoro University.
- Lippi, L., Folli, A., Curci, C., et al. (2022). Osteosarcopenia in patients with chronic obstructive pulmonary diseases: Which pathophysiologic implications for rehabilitation? *International Journal of Environmental Research and Public Health*, 19(21), 14314.
- Martínez-Luna, N., Orea-Tejeda, A., González-Islas, D., et al. (2022). Association between body composition, sarcopenia and pulmonary function in chronic obstructive pulmonary disease. *BMC Pulmonary Medicine*, 22(1), 106.
- Mollica, M., Aronne, L., Paoli, G., et al. (2021). Elderly with COPD: Comorbidities and systemic consequences. *Journal of Gerontology and Geriatrics*, 69, 32–44.
- Moreira, G. L., Manzano, B. M., Gazzotti, M. R., et al. (2014). PLATINO, a nine-year follow-up study of COPD in the city of São Paulo, Brazil: The problem of underdiagnosis. *Jornal Brasileiro de Pneumologia*, 40, 30–37.
- Perrot, L., Greil, A., Boirie, Y., et al. (2020). Prevalence of sarcopenia and malnutrition during acute exacerbation of COPD and after 6 months recovery. *European Journal of Clinical Nutrition*, 74(11), 1556–1564.
- Petermann-Rocha, F., Chen, M., Gray, S. R., et al. (2020). New versus old guidelines for sarcopenia classification: What is the impact on prevalence and health outcomes? *Age and Ageing*, 49(2), 300–304.
- Polosukhin, V. V., Gutor, S. S., Du, R.-H., et al. (2021). Small airway determinants of airflow limitation in chronic obstructive pulmonary disease. *Thorax*, 76(11), 1079–1088.

- Rao, C. M., Singh, P., Maikap, D., et al. (2021). Musculoskeletal disorders in chronic obstructive airway diseases: A neglected clinical entity. *Mediterranean Journal of Rheumatology*, 32(3), 118–123.
- Ridwan, E. S., Wiratama, B. S., Lin, M.-Y., et al. (2021). Peak expiratory flow rate and sarcopenia risk in older Indonesian people: A nationwide survey. *PLOS ONE*, 16(2), e0246179.
- Sepúlveda-Loyola, W., Osadnik, C., Phu, S., et al. (2020). Diagnosis, prevalence, and clinical impact of sarcopenia in COPD: A systematic review and meta-analysis. *Journal of Cachexia, Sarcopenia and Muscle*, 11(5), 1164–1176.
- Supriya, R., Singh, K. P., Gao, Y., et al. (2021). A multifactorial approach for sarcopenia assessment: A literature review. *Biology*, 10(12), 1354.
- Tsekoura, M., Tsepis, E., Billis, E., et al. (2020). Sarcopenia in patients with chronic obstructive pulmonary disease: A study of prevalence and associated factors in Western Greek population. *Lung India*, 37(6), 479–484.
- Trajanoska, K., Schoufour, J. D., Darweesh, S. K., et al. (2018). Sarcopenia and its clinical correlates in the general population: The Rotterdam study. *Journal of Bone and Mineral Research*, 33(7), 1209–1218.
- Vaes, A. W., Sillen, M. J. H., Goërtz, Y. M. J., et al. (2021). The correlation between quadriceps muscle strength and endurance and exercise performance in patients with COPD. *Journal of Applied Physiology*.
- van Bakel, S. I., Gosker, H. R., Langen, R. C. J., et al. (2021). Towards personalized management of sarcopenia in COPD. *International Journal of Chronic Obstructive Pulmonary Disease*, 25–40.
- Varmaghani, M., Dehghani, M., Heidari, E., et al. (2019). Global prevalence of chronic obstructive pulmonary disease: Systematic review and meta-analysis. *Eastern Mediterranean Health Journal*, 25(1), 47–57.
- Wang, Y., Xu, J., Meng, Y., et al. (2018). Role of inflammatory cells in airway remodeling in COPD. *International Journal of Chronic Obstructive Pulmonary Disease*, 3341–3348.
- Wu, J.-F., Jia, J., Chen, P., et al. (2023). Sarcopenia and its clinical correlation in elderly chronic obstructive pulmonary disease: A prospective cohort study. *European Review for Medical and Pharmacological Sciences*, 27(20).
- Zhao, X., Su, R., Hu, R., et al. (2023). Sarcopenia index as a predictor of clinical outcomes among older adult patients with acute exacerbation of chronic obstructive pulmonary disease: A cross-sectional study. *BMC Geriatrics*, 23(1), 89.
- Zhao, Y., He, Q., & Xu, Z. (2024). Impact of sarcopenia on the quality of life and mobility in elderly patients with chronic obstructive pulmonary disease. *Physical & Occupational Therapy in Geriatrics*, 1–11.