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# MALNUTRITION RISK AS A DETERMINANT OF RESPIRATORY FUNCTION IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE

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## *Abstract*

*Chronic obstructive pulmonary disease (COPD) is a chronic lung disease characterized by abnormalities of the airflow. The scientific literature points out that patients with COPD often have diet-related comorbidities, which can correlate with worse patient outcomes and higher mortality. The aim of this study was to assess the risk of malnutrition and to determine whether the severity of risk has an impact on respiratory and pulmonary function in adult patients with COPD. This cross-sectional study (September 2023–May 2024) involved 68 patients (55% men) aged between 40 and 75 years who suffered from COPD and were in the Special Hospital for Pulmonary Disease day clinic for Pulmonary rehabilitation. The collection of personal data, anthropometric measurements, the risk of malnutrition assessment (Nutrition Risk Score-2002, NRS-2002) and pulmonary function were performed according to standard protocols during the visit to the hospital. For further analysis, the patients were divided into three groups according to the points achieved on the NRS-2002 (group 1 = NRS-2002 score 1; group 2 = NRS-2002 score 2; group 3 = NRS-2002 score ≥ 3). Of the total study sample, 26.5% of patients are at risk for malnutrition according to the NRS-2002. There are no differences in diaphragm thickness at the end of inspiration ($p = 0.448$) or at the end of expiration ($p = 0.708$) between groups of patients with different risks of malnutrition. Neither forced vital capacity (FVC) ($p = 0.731$) nor forced expiratory volume in one second (FEV1) ($p = 0.058$) differed between groups. However, patients with a high risk of malnutrition (NRS-2002 score ≥ 3) had the lowest ($p = 0.012$) maximum inspiratory pressure (MIP). A quarter of patients with COPD are at risk of severe malnutrition, which can lead to further deterioration in respiratory function. These findings emphasize the importance of using screening tools for malnutrition and initiate nutritional support to improve patient outcomes.*

***Keywords**: COPD, diaphragm thickness, maximal inspiratory pressure, NRS-2002, spirometry results*

## Introduction

In the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines chronic obstructive pulmonary disease (COPD) is defined as a heterogeneous lung disease characterized by chronic respiratory symptoms such as dyspnoea, cough, chronic sputum production and exacerbations (GOLD, 2025). The symptoms are caused by abnormalities in the airways, namely bronchitis or bronchiolitis, and/or emphysema leading to progressive airway obstruction. In COPD patients, airway obstruction can be confirmed by spirometry (forced expiratory volume in the first second - FEV1; forced vital capacity – FVC) (Celli et al., 2022). In addition to these pulmonary symptoms, COPD is recognized as a systemic disease with numerous extrapulmonary manifestations and comorbidities, including weight loss, muscle mass loss, osteoporosis, cardiovascular disease, and metabolic syndrome (Decramer et al., 2008). Moreover, it has been estimated that patients with COPD have increased resting energy expenditure, resulting in significant physical impairment and decreased physical activity (Collins i sur., 2019). Furthermore, patients with COPD have been observed to have reduced energy intake and an imbalanced intake of macronutrients and micronutrients due to various pulmonary manifestations, such as shortness of breath and fatigue, as well as other factors, including anxiety, depression, anorexia, periodontal disease, loss of taste, dysphagia, difficulty chewing or swallowing, and loneliness (Ludisio et al., 2016; Grönberg et al., 2005). All of these outcomes may lead to the two most pronounced manifestations of COPD – malnutrition and sarcopenia. Malnutrition is defined as a condition resulting from inadequate intake or malabsorption of nutrients. In most cases, it leads to a change in body composition, which manifests as a reduction in lean mass and decreased body cell mass. However, it must be emphasized that although malnutrition is usually associated with underweight, it is now known to occur in overweight and obese people as well (WHO, 2024a). Malnutrition is a common clinical outcome in patients with COPD (25-40%), occurring even in patients with early-stage COPD and contributing to the deterioration of respiratory function (Decramer et al., 2008; Vermeeren et al., 2006). Sarcopenia may result from catabolic imbalance, inadequate nutritional intake, impaired protein synthesis, systemic inflammation, oxidative stress, chronic hypoxia and hypercapnia, endocrine dysfunction, aging, and medication use (Ma et al., 2022). According to available literature, 21.6% of patients with COPD have also developed sarcopenia, which may occur in both peripheral and inspiratory muscles (Benz et al., 2017). The degree of muscle weakness positively correlates with the severity of the underlying disease (McDonald et al., 2014).

These findings further highlight the importance of systematic nutritional assessment and individualized pulmonary rehabilitation with integrated nutritional support and physical activity as part of a comprehensive approach to managing patients with COPD (NICE, 2019). A nutritional assessment should be performed at the first patient contact and whenever there is a change in patient's condition during regularly medical visits or pulmonary rehabilitation (NICE, 2019). Except for monitoring weight status, in clinical practice malnutrition can be detected by analyzing body composition using bioelectrical impedance, assessing handgrip strength, or with several screening tools such as the Malnutrition Universal Screening Tool, the Mini Nutritional Assessment, and the Nutritional Risk Score. According to the available literature, the Nutritional Risk Score is recomended for COPD patients (Charney and Malone, 2015;

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Kondrup et al., 2003; Lee and Neiman, 2013; Munos and Bernstein, 2019; NICE, 2019; Vrbica et al., 2018).

The aim of this study was to estimate the proportion of COPD patients at risk of malnutrition using NRS-2002 and to determine whether the severity of malnutrition risk affects respiratory and pulmonary function in these patients.

## Materials and methods

### *Study design*

This cross-cestional study was conducted at the Special Hospital for Pulmonary Diseases (Zagreb, Croatia) from September 2023 to May 2024. The study involved 68 patients (55% men) aged 40 to 75 years, which is sufficient, as a preliminary power analysis (statistical power 80%, $\alpha = 0.05$, effect size 0.15, sex and smoking as predictive factors) performed with G*Power software (version 3.1.9.2; Heinrich Heine University Düsseldorf, Düsseldorf, Germany) indicated a minimum of 66 patients. The patients were recruited through day clinic during pulmonary rehabilitation where they also underwent medical history assessment, anthropometric measurements, spirometry, and diaphragm ultrasound. General information about the patients was obtained through interviews during pulmonary rehabilitation and retrieved from the Hospital Information System (IN2 Ltd., Zagreb, Croatia). All patients were examined according to the Global Initiative for Chronic Obstructive Lung Diseases (GOLD) scale (GOLD, 2025). Patients were excluded if they were receiving long-term oxygen therapy or had coexisting asthma. Additional exclusion criteria included the use of systemic corticosteroids within the past six months, the presence of an implanted pacemaker or other electrical device, and neuromuscular disorders or phrenic nerve damage. Individuals with a history of stroke resulting in residual hemiparesis or those who had undergone lung surgery were also not eligible. Furthermore, patients with autoimmune, neurological, or other systemic diseases that could impair respiratory function were excluded from the study.

The study was conducted in accordance with the principles of the Declaration of Helsinki, and all research protocols were approved by the Ethics Committee of the School of Medicine, University of Zagreb (reference number: 251-59-10106-23-111/203, class: 641-01/23-02/01). During pulmonary rehabilitation, all patients were informed about the study procedure and their right to object to the study at any time. All patients gave their written consent to participate in the study.

### *Anthropometric and body composition analyzes*

Anthropometric measurements and body composition assessments were performed during the patients' visits to the pulmonary rehabilitation day clinic. Height was measured to the nearest 0.1 cm using a stadiometer (SECA 799, Hamburg, Germany), while body weight was measured to the nearest 0.1 kg using a digital scale integrated with a bioelectrical impedance analyzer (TANITA MC-780 MA P, Tanita Corp., Tokyo, Japan). Body composition analysis was performed using a bioelectrical impedance analyzer (TANITA MC-780 MA P, Tanita Corp., Tokyo, Japan). For this study, we recorded values for fat free mass (kg), body fat (%), and skeletal muscle mass (kg) from all measurements obtained. In addition, the analyzer provided calculated measures of body mass index (BMI) from height and weight, and skeletal muscle mass index (SMMI) from height and skeletal muscle mass. The cut-off values for BMI were adopted from the World Health Organization (WHO, 2024b) and for SMMI from the European Society for Clinical Nutrition and Metabolism (Cederhol et al., 2017).

### *Nutrition Risk Score – 2002*

The Nutritional Risk Score 2002 (NRS-2002) was used as a screening tool to assess the risk of malnutrition in each patient during pulmonary rehabilitation. The NRS-2002 consists of two parts: (1) assessment of nutritional status (weight loss, BMI; reduction in food intake); (2) assessment of disease severity. The final score is calculated as the sum of the individual criteria, and patients with a score of $\geq 3$ are at high risk of malnutrition (Kondrup et al., 2003; Hersberger et al., 2020).

### *Assessment of clinical outcomes*

Spirometry (FEV1 and FVC values) was performed on each patient using a Medisoft HypAir PFT system (Medisoft, Sorrines, Belgium). An FEV1/FVC ratio less than 0.70 defines airway obstruction. Additionally, FEV1 is used to classify the severity of obstructive lung disease based on the percentage of predicted values (GOLD, 2025):

- Mild COPD: FEV1 $\geq$ 80% predicted (GOLD I stage)
- Moderate COPD: 50% $\leq$ FEV1 < 80% predicted (GOLD II stage)
- Severe COPD: 30% $\leq$ FEV1 < 50% predicted (GOLD II stage)
- Very severe COPD: FEV1 < 30% predicted or FEV1 < 50% predicted with chronic respiratory failure (GOLD IV stage)

Inspiratory muscle strength was evaluated by measuring maximal inspiratory pressure (MIP) using a handheld device (Power Breathe, Powerbreathe International Ltd., Southam, England, UK). Patients performed maximal inhalations against resistance while seated and wearing a nasal clip. The device software calculates the expected MIP value based on age and sex. The cut-off values indicating weakness of the diaphragm inspiratory muscles are as follows (Sachs et al., 2009; Rodrigues et al., 2017):

- < 60 cmH2O in adults under 40 years
- < 50 cmH2O in adults between 40 and 80 years
- < 40 cmH2O in adults over 80 years

Diaphragm thickness was assessed using ultrasonography (Mindray DC-8, Mindray Medical International Ltd., Shenzhen, Guangdong, China), with patients in a supine position. Measurements were taken at the end of both inspiration and expiration, using a high-frequency linear probe placed in the intercostal space near the anterior and mid-axillary lines. The cut-off values at the end of inspiration are 2.1 ± 0.4 mm (1.3–3.0 mm) in men and 1.9 ± 0.4 mm (1.1–2.7 mm) in women, while at the end of expiration they are 2.8 ± 0.6 mm (1.7–3.9 mm) in men and 2.5 ± 0.6 mm (1.3–3.7 mm) in women (Boussuges et al., 2021).

### *Statistical analysis*

Statistical analysis was performed using IBM SPSS (IBM SPSS Statistics for Windows, Version 23.0, Armonk, NY, USA: IBM Corp.). All continuous variables were presented as mean and standard deviation, as they were normally distributed according to the Shapiro-Wilk test. Categorical variables were presented as percentages. For further analysis, patients were divided into three groups based on the estimated NRS-2002 score (group 1 – mild risk of malnutrition: score equal to 1; group 2 – moderate risk of malnutrition: score equal to 2; group 3 – high risk of malnutrition: score $\geq 3$). Differences between groups were tested using a one-way analysis of variance (ANOVA) with post hoc Bonferroni test for continuous variables and a chi-square test or Fisher's exact test for categorical variables. The correlations were tested using Pearson's correlation coefficient. The significance level was set at $\alpha = 0.05$ for all analyses.

## Results and discussion

To achieve the aims of this study, the risk of malnutrition was assessed in 68 patients, 55.9% men and 44.1% women, with an average age of 66.6 ± 8.5 years. The demographic profile of these respondents reflects the global epidemiology of the disease, which primarily affects men and older adults (Adeloye et al., 2022). Notably, 42.6% of respondents are current smokers, 55.9% are former smokers, and only one respondent

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has never smoked, highlighting smoking as a major factor in the development of the disease (Kohansal et al., 2009).

Based on the NRS-2002, 26.5% of patients (score ≥ 3) from the present study were at risk of malnutrition (Figure 1). This finding was lower than estimated in 2016 among outpatients from Dubrava University Hospital in Zagreb. However, the risk of malnutrition was assessed using the MNA, not the NRS-2002, in this study (Matković et al., 2017). According to the available literature, the proportion of COPD patients at risk of malnutrition was estimated to be two to three times higher than in the present study (Benedik et al., 2011; Hsu et al., 2014; Arslan et al., 2016; Ogan et al., 2020; Huang et al, 2021). In addition, no difference was found in the risk of malnutrition between patients with respect to sex (p = 0.840), nor was any correlation between patients' age and the risk of malnutrition (r = -0.018; p = 0.884).

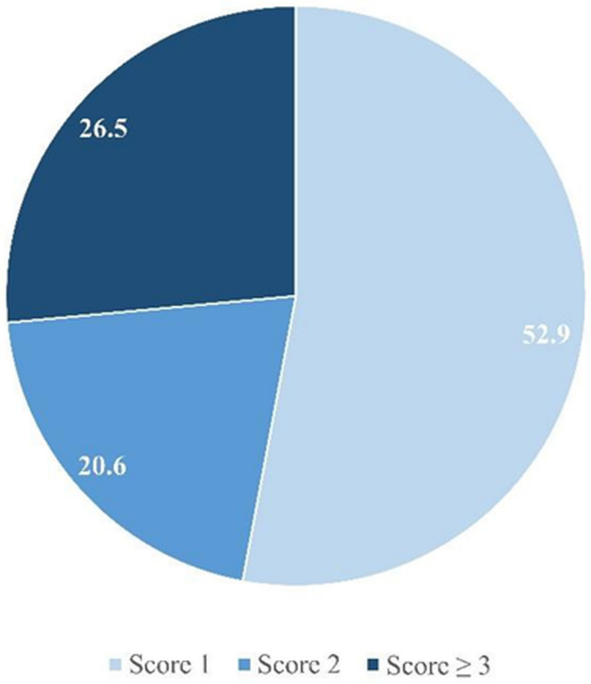



**Figure 1.** *Distribution of patients (N = 68) with COPD according to the NRS-2002*

Malnutrition is a major problem in COPD patients as it leads to muscle wasting and consequently a decrease in respiratory muscle strength (Mannino and Buist, 2007). This can increase the rate of exacerbations and length of hospitalization, worsening patients' quality of life (May and Li, 2015; Safiri et al., 2022). In addition, malnutrition can increase fatigue and reduce physical performance (Engelen et al., 2000; Decramer at al., 2008; Cederholm et al., 2017). Therefore, appropriate nutritional therapy is crucial for maintaining the overall health and quality of life of COPD patients (Collins et al., 2013; Nguyen et al., 2020; Fekete et al., 2023).

The anthropometric characteristics between the patients with different risk of malnutrition stratified by their NRS-2002 scores are shown in Table 1. The study results indicate that the total population studied is, on average, overweight, with an estimated BMI of 25.6 ± 5.4 kg/m². Recently, higher BMI in COPD patients was also observed in the study by Muršić et al. (2024), consistent with worldwide observations. In the present study, patients with a higher risk of malnutrition (NRS ≥ 3) exhibited lower body weight (65.5 ± 17.2 kg, p < 0.001) and a lower BMI (21.1 ± 4.8 kg/m², p < 0.001) than patients with a lower score. However, the group at higher risk of malnutrition still had adequate body weight, while patients at low risk were overweight. In addition, body fat percentage and SMMI were also significantly lower in the high malnutrition risk group (p < 0.001 and p = 0.013, respectively), indicating potential muscle loss. Similar to our study, it was previously shown that BMI and other anthropometric parameters such as body fat, fat-free mass and arm circumference are lower in COPD patients with a higher risk of malnutrition (Benedik et al., 2011; Ogan et al., 2020; Huang et al, 2021).

The clinical outcomes between the groups of COPD patients are presented in Table 2. In the present study, most of patients had mild COPD, according to the GOLD stage. We did not find a difference in

**Table 1.** Anthropometric characteristic of the patients with COPD according to the Nutrition Risk Score 2002 [1]

| Variables | Total (N = 68) | Nutrition Risk Score 2002 | | | p Values* |
|---|---|---|---|---|---|
| | | Score 1 (n = 36) | Score 2 (n = 14) | Score ≥ 3 (n = 18) | |
| **Weight, kg** | 75.6 ± 17.5 | 83.6 ± 15.9[a] | 67.2 ± 9.9[b] | 65.5 ± 17.2[b] | < 0.001 |
| **Height, cm** | 171.7 ± 8.0 | 170.8 ± 7.3 | 169.6 ± 6.2 | 175.1 ± 9.7 | 0.096 |
| **BMI, kg/m²** | 25.6 ± 5.4 | 28.6 ± 4.4[a] | 23.3 ± 2.9[b] | 21.1 ± 4.8[b] | < 0.001 |
| **BMI category, n, (%):** | | | | | |
| **Underweight** | 5, (7.5) | 0, (0.0) | 0, (0.0) | 5, (27.8) | < 0.001 |
| **Normal** | 32, (46.3) | 11, (30.6) | 11, (76.9) | 10, (55.6) | |
| **Overweight** | 11, (16.4) | 8, (22.2) | 2, (15.4) | 1, (5.6) | |
| **Obesity** | 20, (29.9) | 17, (47.2) | 1, (7.7) | 2, (11.1) | |
| **Fat free mass, kg** | 54.4 ± 10.7 | 56.8 ± 10.7 | 50.7 ± 8.5 | 52.3 ± 11.5 | 0.128 |
| **Body fat, %** | 26.9 ± 9.3 | 31.6 ± 8.2[a] | 24.7 ± 4.6[b] | 19.2 ± 8.5[b] | < 0.001 |
| **SMMI, kg/m²** | 7.4 ± 1.2 | 7.8 ± 1.2[a] | 6.9 ± 1.0[a] | 6.9 ± 2.7[b] | 0.013 |
| **SMMI category, n, (%):** | | | | | |
| **Reduced** | 14, (20.0) | 2, (5.6) | 3, (23.1) | 9, (50.0) | 0.001 |
| **Normal** | 54, (80.0) | 34, (94.4) | 11, (76.9) | 9, (50.0) | |

BMI – body mass index; SMMI – skeletal muscle mass index; [1] Data are shown as mean ± standard deviation or percentage, depending on the type of variable. * Differences between groups were tested using one-way analysis of variance with post hoc Bonferroni test (differences is indicated with [a,b]) for continuous variables and Chi-square test/Fisher's exact test for categorical variables (p < 0.05).

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the distribution of patients in risk of malnutrition across the different GOLD stages, which may be due to the small sample size and attrition in the groups. This finding contradicts the available literature, which suggests that patients with a higher GOLD stage have a higher risk of malnutrition, regardless of whether they are hospitalized or outpatients or whethever the tools are used to detect malnutrition (Benedik et al., 2011; Hsu et al., 2014; Arslan et al., 2016; Ogan et al., 2020; Huang et al, 2021).

Previous studies have demonstrated that a higher risk of malnutrition and loss of muscle mass contribute to poorer respiratory function, highlighting their influence on disease progression (Hsu et al., 2014; Arslan et al., 2016; Mete et al., 2018; Huang et al., 2021). Given these findings, it is expected that our patient cohort will also show similar patterns of respiratory health deterioration associated with nutritional risk. However, according to the results shown in Table 2, no statistically significant differences were found between the groups in FVC nor in FEV1. In contrast, it has been foun that both inpatients and outpatients COPD patients at risk of malnutrition, as assessed using NRS-2002, had lower values of FEV1, FVC, and FEV1/FVC ratio (Arsla et al., 2016; Huang et al., 2021). Moreover, Ogan et al. (2020) found that patients (GOLD stage III and IV) at risk of malnutrition assessed with the NRS-2002 had a lower FEV1 than patients without nutritional risk, while FVC and FEV1/FVC ratio did not differ between patient groups. Additionally, another study that evaluated the risk of malnutrition using the MNA found that a higher risk is associated with lower FEV1 and FVC values (Hsu et al., 2014). Several factors could explain why we did not found association between malnutrition and poorer FEV1 and FVC. First of all, a small sample size may limit statistical sensitivity, making it difficult to detect significant associations. Patient heterogeneity, including different disease stages and comorbidities, could also obscure the association between diet and lung function. In addition, compensatory mechanisms may contribute to lung function remaining stable in some individuals despite malnutrition. Analyzing more specific subgroups or conducting long-term follow-up could provide deeper insights.

As far as we know, this is one of the few studies that have investigated the contribution of malnutrition to inspiratory muscle strength and function. Aa shown in Table 2, MIP was significantly lower ($p = 0.012$) in patients with higher risk of malnutrition, indicating decreased respiratory muscle strength. However, no differences in diaphragm thickness were observed. The diaphragm functions may be reduced in malnourished individuals due to muscle wasting, which may impair respiratory function. However, these findings are not fully confirmed in the literature, as the studies show contradictory results (Dureuil and Matuszczak, 1998; Hamnegård et al., 2002). Diaphragm wasting plays a significant role in reducing contractile performance in COPD patients, and malnutrition may further exacerbate this process by contributing to muscle atrophy (Baria et al., 2014; Mu and Zhang, 2024, Ottenheijm et al., 2007). Since the causes of diaphragm wasting in COPD are complex and not fully understood, identifying effective therapeutic targets remains challenging. Indeed, proper nutrition support is essential for maintaining diaphragm thickness and function, as studies have shown that enteral nutrition can improve inspiratory muscle strength and overall prognosis in mechanically ventilated COPD patients (Li et al., 2020).

The results of the present study suggest a possible relationship between raspiratory function and the risk of malnutrition in adults and elderly COPD patients. The results also suggest that the risk of malnutrition needs to be regularly monitored in order to optimize the treatment approach during pulmonary rehabilitation and achieve better clinical outcomes. These results emphasize the importance of nutritional support in the context of pulmonary rehabilitation. This study with COPD patients has some limitations. With a sample size of 68 patients, the study may not have sufficient statistical power to detect subtle associations. In addition, most participants are classified as GOLD 1, have a normal BMI and SMMI, and 52.9% have a low risk of malnutrition, which may limit the applicability of the results to more severe COPD cases or malnourished individuals. Furthermore, patients had COPD diagnosed between 6 and 30 years ago, and for some with COPD for more than 20 years, data were not entered accurately into the computer program, making it impossible to objectively estimate the exact time of COPD diagnosis. Therefore, we could not control the analysis for this potential bias. These characteristics may limit the study's ability to capture the full impact of malnutrition on lung function and diaphragm thickness. Future studies that include a more diverse COPD population, particularly those with advanced disease and higher malnutrition risk, are needed to gain a more comprehensive understanding of these associations.

## Conclusions

These results suggest that the risk of malnutrition may be related to respiratory muscle function and strength in COPD patients. Although spirometry parameters (FVC and FEV1) did not differ significantly, the reduced MIP in patients at risk of malnutrition highlights the importance of incorporating routine nutritional assessment and timely intervention

**Table 2.** Average results on respiratory function tests among patients with COPD across Nutrition Risk Score 2002 categories[1]

| Variables | Total (N = 68) | Nutrition Risk Score 2002 | | | p Values* |
|---|---|---|---|---|---|
| | | Score 1 (n = 36) | Score 2 (n = 14) | Score ≥ 3 (n = 18) | |
| **GOLD stages, n, (%):** | | | | | |
| **stage I** | 17, (25.0) | 10, (27.8) | 3, (21.4) | 4, (2.2) | 0.337 |
| **stage II** | 27, (39.7 | 15, (41.7) | 6, (42.9) | 6, (33.3) | |
| **stage III** | 16, (23.5) | 8, (22.2) | 3, (21.4) | 5, (27.8) | |
| **stage IV** | 8, (11.8) | 3, (8.3) | 2, (14.3) | 3, (16.7) | |
| **FVC, %** | 96.4 ± 18.3 | 96.2 ± 18.4 | 105.6 ± 15.9 | 89.4 ± 17.5 | 0.731 |
| **$FEV_{1,}$ %** | 62.0 ± 21.2 | 63.9 ± 21.5 | 61.3 ± 21.1 | 58.8 ± 21.6 | 0.058 |
| **MIP, $cmH_2O$** | 69.8 ± 20.8 | 76.5 ± 18.2[a] | 66.1 ± 18.6[b] | 59.5 ± 23.3[c] | 0.012 |
| **$DT_{max}$, mm** | 2.4 ± 0.6 | 2.4 ± 0.6 | 2.4 ± 0.6 | 2.2 ± 0.5 | 0.448 |
| **$DT_{min,}$ mm** | 1.7 ± 0.5 | 1.8 ± 0.5 | 1.6 ± 0.4 | 1.6 ± 0.4 | 0.708 |

FVC – forced vital capacity; $FEV_1$ – forced expiratory volume in the first second; MIP – maximal inspiratory pressure; $DT_{min}$ – the diaphragm thickness at the end of expiration; $DT_{max}$ – diaphragmatic thickness at the end of inhaletion; [1] Data are shown as mean ± standard deviation or percentage, depending on the type of variable. * Differences between groups were tested using one-way analysis of variance with post hoc Bonferroni test (differences is indicated with [a,b]) ($p < 0.05$).

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into standard COPD care protocols. Screening for malnutrition risk with the NRS-2002 tool could facilitate timely nutritional support, potentially improving respiratory function and overall patient outcomes.

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