Original article

Evaluation of the functional status of patients with chronic obstructive pulmonary disease via the modeling approach

Sengul Cangur[1*], EgeGulec Balbay[2], Handan Ankarali[3], Sinem Berik[4]

Abstract

Background: Chronic obstructive pulmonary disease (COPD) is common worldwide. COPD has negative effects on the quality of life of the patient due to restrictions on daily activities. It can cause a major healthcare burden according to the stage and grade of disease.

Objective: The purpose of this study was to determine the physical and psychological functional capacity factors affecting patients' functional performance and to develop a COPD-specific functional status model using these factors.

Methods: A group of randomly selected patients (n=183) diagnosed with COPD at a university hospital in Turkey comprised the study sample. Physical examinations were carried out on all patients and they completed questionnaires that included socio demographic and disease characteristics, the Hospital Anxiety and Depression Scale, Functional Performance Inventory and Short Form-36 Survey. The proposed theoretical model was analyzed in the LISREL program using the structural equation modeling approach.

Results: We found that the independent latent variable of the physiological functional capacity yielded a significant positive effect on the dependent latent variable of functional performance, while the psychological functional capacity produced no significant effect.

Conclusions: The COPD-specific functional status model should prove to be an effective and beneficial tool for issues such as treatment maintenance and for the preservation or improvement of patients' quality of life. [*Ethiop.J. Health Dev.* 2019; 33(2):81-87]

Keywords: Chronic obstructive pulmonary disease, functional status, functional performance, functional capacity, structural equation modeling

Introduction

Chronic obstructive pulmonary disease (COPD) is one of the leading causes of morbidity and mortality in the world(1),with the social and economic burden that results from this disease steadily increasing(1,2).According to World Health Organization's *Global Health Estimates* report, COPD causes 3 million deaths per year. COPD is responsible for 5.3% of all deaths, which makes it the third leading cause of death in the world. It has been estimated that by 2045 and 2060, COPD will rank third and fourth, respectively, in terms of mortality worldwide(3).

Patients with COPD experience a variety of symptoms such as dyspnea, fatigue, depression, and impaired functional performance (4); and patients' gradually decreasing breathing capacity and impaired ability to perform day-to-day activities negatively affect their quality of life(5). The evaluation of functional status is highly important in the determination of the quality of life status in COPD patients, as well as for all other chronic diseases. If the functional status of a COPD patient is known in detail, the maintenance of a clinically effective treatment can be provided that will allow for normalization of the decreased quality of life ,i.e. which will improve or stabilize it. Functional status is a multidimensional concept, including the dimensions of functional performance, functional capacity, functional reserve and capacity utility(6). The term 'functional performance' indicates the physical, psychological, social, occupational, and spiritual activities carried out by individuals in the normal course of their lives in order to meet their basic needs, fulfill their usual roles, and maintain their health and wellbeing(7). Functional capacity involves the disease-associated maximum physiological and psychological potential to perform the activities of daily living(8). In routine clinical practice, functional status can be measured by different methods. Kock s*et al.*(7) developed functional capacity and functional performance tools to be used for measuring functional status in COPD patients, considering that both its physical and psychological aspects should be evaluated. Yeh *et al.*(8)propose a functional status model that includes functional performance, functional capacity, disease severity, age, health perception and more. The important predictors of functional status found in the literature involve factors such as age, forced expiratory volume in one second (FEV1), disease severity, dyspnea, fatigue, depression, anxiety, health perception and exercise tolerance (8-19).However, very few studies have used the modeling approach(4,8,10,14,15).This study aimed to determine the physical and psychological functional capacity factors affecting the functional status of COPD patients

[1*]Department of Biostatistics and Medical Informatics, Faculty of Medicine, Duzce University, 81620, Duzce, Turkey, e-mail: sengulcangur@duzce.edu.tr

[2]Department of Chest Diseases, Faculty of Medicine, Duzce University, 81620, Duzce, Turkey, e-mail: egegulecbalbay@gmail.com

[3] Department of Biostatistics and Medical Informatics, Faculty of Medicine, Istanbul Medeniyet University, 34700, Istanbul, Turkey, e-mail: handanankarali@gmail.com

[4] Department of Chest Diseases, Adana Numune Training and Research Hospital, 01260, Adana, Turkey, e-mail: sinemberik@hotmail.com

and to develop a COPD-specific functional status model using the relevant factors.

Materials and methods

Subjects and design: First, a priori minimum sample size acceptable for structural equation model with the number of latent variables 3 and the number of manifest variables 13 was calculated to be 119 participants at 80% power and 5% type-I error. A total of 200 patients registered at the Duzce University Research and Practice Hospital Pulmonology Polyclinic (Duzce, Turkey) between 2014 and 2017, who were diagnosed with COPD, had no physical or mental disabilities and were approved for participation, were included in the study. However, some were excluded due to their severe concomitant diseases, leaving 183 participants remaining in the study. This study was a cross-sectional one. All patients completed questionnaire forms that included their socio demographic and disease characteristics, the Hospital Anxiety and Depression Scale, Functional Performance Inventory and Short Form-36 Survey.

Data-collection tools

i. Functional performance: The Functional Performance Inventory (FPI), developed by Leidy (20), consists of six dimensions including body care, household maintenance, physical exercise, recreation, spiritual activities and social activities, with a total of 62 items within these six dimensions. A Turkish validity and reliability study of the scale was conducted by Ozkan*et al.*(21), who found the overall Cronbach alpha(Cα)of the scale to be 0.87. In this study, the Cα for the six dimensions varied between 0.87 and 0.99, with an overall value of 0.98.

ii. Health perception and energy/fatigue: The Short Form-36 (SF-36),developed by Ware and Sherbourne(22), is composed of eight subscales, of which ‘general health perception’ (SF_GENER), with five items, and ‘energy’ (SF_ENERG), with four items, were used in this study. A higher total score indicates better health perception or higher stamina. A Turkish validation and reliability study of the SF-36 was conducted by Kocyigit*et al.*(23), who found the Cα coefficients of the two subscales to be 0.76 and 0.73, respectively. In this study, the Cα for the ‘health perception’ subscale was 0.90 and for the ‘energy’ subscale 0.94.

iii. FEV1value: The FEV1 is the volume of air that a patient is able to exhale in the first second of forced expiration. The FEV1 value is measured in liters using a spirometer and expressed as a percentage of the predicted values for that individual. In this study, FEV1 values were measured by a Carefusions pirometer in accordance with the American Thoracic Society/European Respiratory Society (ATS/ERS) task force standardization guideline for spirometry(24). The level of disease severity was evaluated by measuring the percentage of the predicted FEV1 value according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines(25).

iv. COPD grade: Based on the GOLD guidelines, the COPD grade (COPD_GRD) is obtained via spirometric criteria by measuring FEV1 and FEV1/FVC (FVC: Forced Vital Capacity) values. Accordingly, the COPD grade is classified as mild (FEV1/FVC<0.7, FEV1≥80%), moderate (FEV1/FVC<0.7, 50%≤FEV1<80%), severe (FEV1/FVC<0.7, 30%≤FEV1<50%) and very severe (FEV1/FVC<0.7, FEV1<30% or FEV1<50% plus chronic respiratory failure)(25).

v. Anxiety and depression: The Hospital Anxiety and Depression Scale (HADS), developed by Zigmond and Snaith(26), has a total of 14 items and is divided into ‘anxiety’ and ‘depression’ subscales with seven items each. The higher the score, the more severe is the depression or anxiety. A Turkish validity and reliability study for HADS was conducted by Aydemir*et al.*(27), who found the Cα coefficients of the ‘depression’ and ‘anxiety’ subscales to be 0.85 and 0.78, respectively. In this study, the Cα was 0.92 for the ‘anxiety’ subscale and 0.88 for the ‘depression’ subscale.

vi. Dyspnea: The Medical Research Council (MRC) five-point scale for breathlessness was used to assess dyspnea(28). Dyspnea was rated by the patient with options ranging from 0 (not breathless except for exertion) to 4 (too breathless to leave house or breathless when dressing or undressing).

Structural equation modeling: Because of its capability to analyze complex theoretical models and its practicability, the structural equation modeling (SEM) approach is preferred when studying causal relationships and latent constructs among variables(29).The structural equation model is divided into two parts: (*i*) structural part connecting the constructs to each other: $\eta = \mathrm{B}\eta + \Gamma\xi + \zeta$; and (*ii*) measurement part, which connects the observed variables to the latent variables: $x = \Lambda_x \xi + \delta$, $y = \Lambda_y \eta + \varepsilon$.Here,η represents a vector of endogenous/dependent latent variables, ξ is a vector of exogenous/independent latent variables, ζ is the error or disturbance term vector, Β and Γ are the structural coefficients of endogenous and exogenous latent variables, x and y are vectors of exogenous and endogenous manifest variables, Λ_x and Λ_y are the factor loadings matrices, δ and ε are vectors of measurement errors(30).The goal of SEM is to explain the system of correlative dependent relationships between one or more manifest variables and latent constructs simultaneously. It is able to determine how a theoretical model that indicates relevant systems is supported by sample data, i.e. it provides an estimation of relationships between the main constructs. A great many fit indices have been developed, since there is no single criterion for the theoretical model fit evaluation obtained as a result of SEM(31,32). Consequently, the model fitness was evaluated by selecting the most suitable model fit indices, i.e. (χ^2/df), the Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Goodness of Fit Index

(GFI), Adjusted Goodness-of-Fit Index (AGFI), Standardized Root Mean Square Residual (SRMR) and Non-Normed Fit Index (NNFI), from the simulation studies in the literature(29).

Statistical analysis: A theoretical functional status model was generated showing the direct and indirect effects of the physiological functional capacity (PHY_FC) and psychological functional capacity (PSY_FC) on FPI. Before the proposed model was tested via SEM, the most important assumptions of the method, the multivariate normality and multicollinearity assumptions, were assessed by Mardia's multivariate normality test and the variance inflation factor (VIF) approach, respectively. Validity studies in the literature were examined for all indicators included in the study (manifest variables, scales, subscales), and a proposed structural model was generated. Confirmatory factor analyses using maximum likelihood estimation (MLE) were implemented in order to support the validity of the scales and achieve the most appropriate measurement models. The Cα coefficients of each scale and subscale were calculated. Prediction values of the proposed model were then obtained by SEM via MLE. The model fitness was evaluated using fit indices such as (χ^2/df), RMSEA, CFI, GFI, AGFI, SRMR and NNFI. The SPSS v.22 and LISREL 8.54 programs were used for statistical analyses, with $p<0.05$ considered statistically significant.

Ethical approval: All procedures in this study were performed in accordance with the 1964 Helsinki Declaration Institutional and National Research Committee ethical standards and later amendments or comparable ethical standards. Local ethical approval was taken from the Duzce University Clinical Research Ethics Committee (Decree no: DU-CREC-2014/2).All individuals who agreed to participate after being informed about the study also gave their written consent.

Results

Included in the study were a total of183 stable COPD patients (mean age 60.04±10.17 years) comprised of175 men and eight women registered at Duzce University Research and Practice Hospital Pulmonology Polyclinic between March 2014 and November 2017 with a diagnosis of COPD who were eligible based on the inclusion criteria. Descriptive statistics regarding the functional performance and PHY-FC and PSY-FC factors of the COPD patients in the study are given in Table 1. A theoretical functional status model was developed to examine the PHY-FC and PSY-FC factors that affect the functional performance of COPD patients (Figure 1).

Table 1: Descriptive statistics regarding functional performance, and physical and psychological functional capacity factors of COPD patients

Functional performance inventory	**n**	**Mean±SD**	**Median**	**Minimum**	**Maximum**
Body care	183	2.68±0.54	3	1	3
Household maintenance	183	1.26±0.84	1.14	0	3
Physical exercise	183	1.31±0.69	1.33	0	3
Recreation	183	2.04±0.82	2.2	0	3
Spiritual activities	183	2.06±1.00	2.2	0	3
Social activities	183	1.98±0.79	2	0	3
Physiological functional capacity					
Age (years)	183	64.04±10.17	65	38	86
FEV1%	183	0.52±0.16	0.51	0.24	1.02
(FEV1/FVC)%	183	0.58±0.08	0.58	0.41	0.81
Cigarette packets/year	176	48.98±25.02	47	10	150
COPD grade	183	-	2	1	4
MRC score	183	-	3	1	5
SF-Energy	183	47.53±24.50	50	5	100
SF-General health	183	46.51±20.61	45	0	100
Psychological functional capacity					
HADS-Anxiety	183	6.20±4.92	5	0	18
HADS-Depression	183	4.48±4.49	3	0	17

SD: Standard Deviation, FEV1%: The percentage of the predicted forced expiratory volume in the first second, FVC%: The percentage of the predicted forced vital capacity, COPD: Chronic Obstructive Pulmonary Disease, MRC: Medical Research Council, SF: Short Form-36 Survey, HADS: Hospital Anxiety and Depression Scale

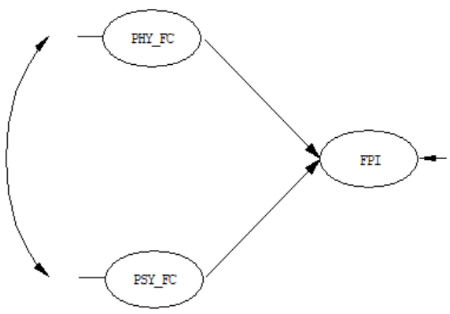

Figure 1: Proposed structural model of COPD-specific functional performance model (COPD: Chronic Obstructive Pulmonary Disease, FPI: Functional Performance Inventory, PSY_FC: Psychological Functional Capacity, PHY_FC: Physiological Functional Capacity)

Mardia's multivariate normality test found that the data provided a multivariate normality assumption (p>0.05). The multicollinearity assumption was detected by the VIF approach and confirmatory factor analyses were conducted in order to achieve the most suitable structural equation model that supported the proposed structural model. The measurement and structural equations for generating the structural model are given in Table 2, together with the data regarding indicators that were included in the model at the end of analyses (variables, scales, subscales) and reliability coefficients of the scales and subscales. Variables such as age, (FEV1/FVC)% and cigarette packets per year were excluded, since they did not cause a significant difference in the model. The Cα values of all scales in the structural model varied between 0.87 and 0.99, which showed that each scale and its subscales had a high level of reliability.

Table 2: Squared multiple correlation of measurement equations and Cronbach alpha values of each subscale

	R^2	Cronbach alpha
Functional Performance Inventory (FPI)		0.98
Body care	0.54	0.99
Household maintenance	0.69	0.95
Physical exercise	0.43	0.87
Pastime entertainment	0.82	0.92
Spiritual activity	0.36	0.98
Social activity	0.82	0.94
Measurement equation of Functional Performance Inventory		
FPI=0.73BODYCARE+0.83HOUSEHLD+0.66PHYSICAL+0.91PASTIME+0.60SPIRIT+0.91SOCIAL		
(7.56) (5.87) (8.31) (5.37) (8.31)		
Physiological Functional Capacity (PHY_FC)		
FEV1%	0.12	
COPD grade	0.18	
MRC score	0.60	
SF-Energy*	0.51	0.94
SF-General health*	0.54	0.90
Measurement equation of Physiological Functional Capacity		
PHY_FC=0.34FEV1%-0.43COPD_GRD-0.78MRC_SCR+0.71SF_ENERG+0.73SF_GENER		
(2.93) (-3.73) (-7.63) (6.37) (7.11)		
Psychological Functional Capacity (PSY_FC)		
HADS-Anxiety	0.09	0.92
HADS-Depression	0.11	0.88
Measurement equation of Psychological Functional Capacity		
PSY_FC= -0.29HADS_ANX -0.32HADS_DEP		
(-5.22) (-5.74)		
Structural Equation		
FPI = 0.98PHY_FC -0.08PSY_FC	0.65	
(4.71) (-0.86)		

*The subscales of Short Form-36 (SF-36) Survey, BODYCARE: Body care, HOUSEHLD: Household maintenance, PHYSICAL: Physical exercise, PASTIME: Pastime recreation, SPIRIT: Spiritual activities, SOCIAL: Social activities, FEV1%: The percentage of the predicted forced expiratory volume in the first second, COPD: Chronic Obstructive Pulmonary Disease, COPD_GRD: COPD grade, MRC_SCR: Medical Research Council score, SF-ENERG: Energy subscale of SF-36, SF-GENER: General health subscale of SF-36, HADS: Hospital Anxiety and Depression Scale, HADS_ANX: HADS-Anxiety, HADS_DEP: HADS-Depression, t-value>1.96 is significant, t-value in parenthesis

At the end of the analysis, the structural equation model showing a COPD-specific functional status model was found to be adequate (Chi-square=69.02, df=54, P=0.082). The model fit indices of the proposed structural equation model are given in Table 3. The model fit indices showed an 'acceptable' fit, since the RMSEA was lower than 0.06, the SRMR lower than 0.07, and the GFI and AGFI indices approached 0.90. Furthermore, the model demonstrated a 'good' fit, since the (χ^2/df) was lower than 2 and the CFI and NNFI indices approached 1. When the model fit indices were evaluated in a combined manner, this proposed model was considered to show an overall 'good' fit. Path diagrams of the model are given in Figures 2 and 3.

Table 3: Model fit indices of chronic obstructive pulmonary disease-specific functional status model

Model fit indices	Value
χ^2	69.02
P	0.082
df (degree of freedom)	54
χ^2/df	1.28
Root Mean Square Error of Approximation (RMSEA)	0.058
Standardized Root Mean Residual (SRMR)	0.065
Comparative-Fit Index (CFI)	0.99
Non-Normed-Fit Index (NNFI)	0.98
Goodness-of-Fit Index (GFI)	0.90
Adjusted Goodness-of-Fit Index (AGFI)	0.86

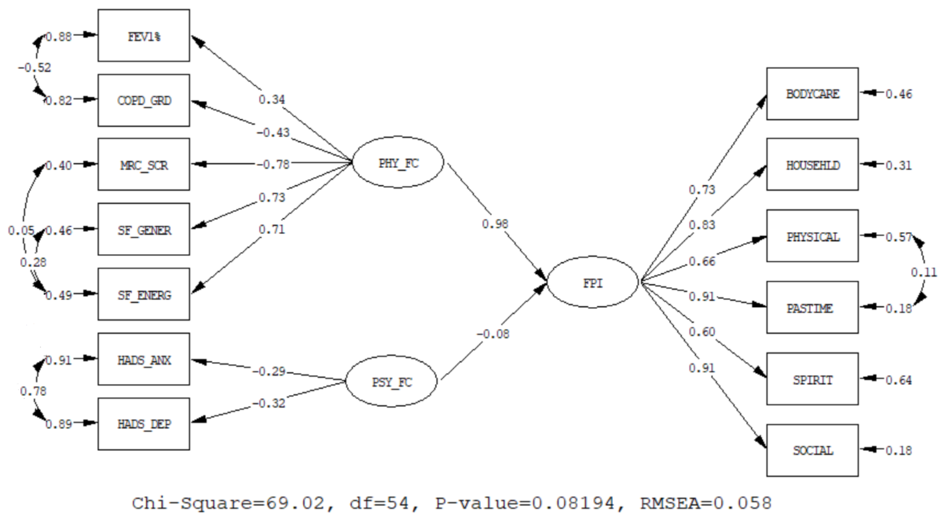

Figure 2: Standardized solution of disease-specific functional performance model (FPI: Functional Performance Inventory, PSY_FC: Psychological Functional Capacity, PHY_FC: Physiological Functional Capacity, FEV1%: The percentage of the predicted forced expiratory volume in the first second, COPD_GRD: Chronic Obstructive Pulmonary Disease grade, MRC_SCR: Medical Research Council score, SF: Short-Form 36 survey, SF_GENER: SF-General health, SF_ENERG: SF-Energy, HADS: Hospital Anxiety and Depression Scale, HADS_ANX: HADS-Anxiety, HADS_DEP: HADS-Depression, BODYCARE: Body care, HOUSEHLD: Household maintenance, PHYSICAL: Physical exercise, PASTIME: Pastime recreation, SPIRIT: Spiritual activities, SOCIAL: Social activities)

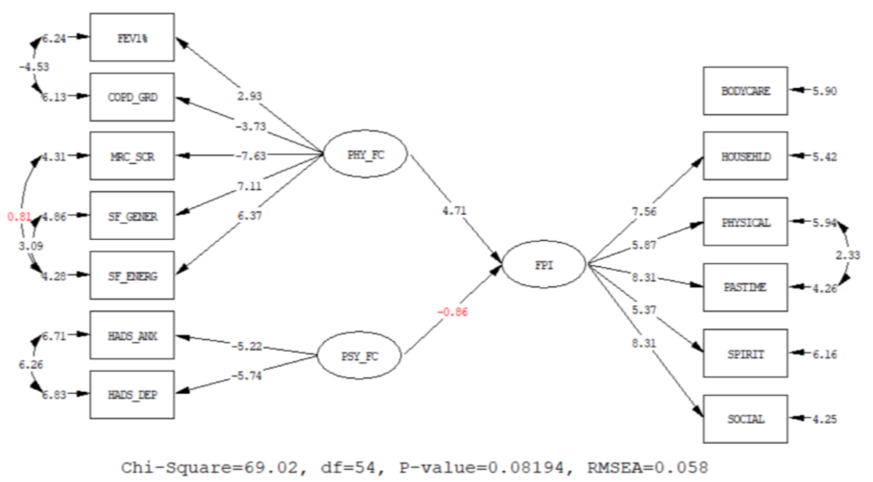

Figure 3: Standardized solution (t-values) of disease-specific functional performance model (t-value>1.96 statistically significant, FPI: Functional Performance Inventory, PSY_FC: Psychological Functional Capacity, PHY_FC: Physiological Functional Capacity, FEV1%: The percentage of the predicted forced expiratory volume in the first second, COPD_GRD: Chronic Obstructive Pulmonary Disease grade, MRC_SCR: Medical Research Council score, SF: Short-Form 36 survey, SF_GENER: SF-General health, SF_ENERG: SF-Energy, HADS: Hospital Anxiety and Depression Scale, HADS_ANX: HADS-Anxiety, HADS_DEP: HADS-Depression, BODYCARE: Body care, HOUSEHLD: Household maintenance, PHYSICAL: Physical exercise, PASTIME: Pastime recreation, SPIRIT: Spiritual activities, SOCIAL: Social activities)

Discussion

COPD has a negative effect on the quality of patients' lives due to its restrictions on their daily activities. In this study, a structural equation model regarding COPD-specific functional status was generated and the total effect levels of the PHY-FC and PSY-FC factors affecting functional performance were calculated. Consequently, the PHY-FC was found to affect functional performance.

Upon examination of the FPI measurement equation in the generated functional status model, parameter estimation values of all indicators affecting the FPI factor (body care, household maintenance, physical exercise, recreation, spiritual activities, and social activities) were statistically significant. All FPI subscales were significant indicators of the FPI evaluated in the COPD patients. The most effective indicators for PHY-FC were the MRC score (MRC_SCR), SF_GENER, SF_ENERG, COPD_GRD and FEV1% value, respectively. The indicators SF_GENER, SF_ENERG and FEV1% had a positive effect on the independent latent variable of PHY-FC, whereas the MRC_SCR and COPD_GRD indicators affected the relevant independent latent variable negatively, i.e. the PHY-FC value increased when the FEV1% value, SF_GENER and SF_ENERG scores increased, but only when the COPD-GRD and MRC_SCR values decreased.

The indicators that were most effective on PSY-FC were the 'depression' and 'anxiety' subscales of the HADS, which had a significant negative effect on the PSY-FC; i.e. the latent variable of PSY-FC decreased as the HADS-Depression and HADS-Anxiety scores increased. In the disease-specific functional status model, the independent latent variable of the PHY-FC had a significant positive effect on functional performance, while this was not the case for the PSY-FC.

In general, the results of the present study were in accordance with the literature(4-21, 33-36).However, studies in the literature on functional status in COPD patients have shown that factors affecting functional performance or functional status were generally analyzed as univariate. Very few studies had adopted a modeling approach, as in the present study(8,10,14,15). Leidy and Traver (15) included acognized functional status model in their study to explain functional status, and Yeh *et al.*(8) generated a functional status model for COPD patients. Kapella *et al.*(14)reported a gradual decrease in functional performance in COPD patients, while Weldam *et al.*(10) explored the extent to which psychological determinants contributed to the daily activities and health-related quality of life in COPD patients.

The MRC_SCR and COPD_GRD indicators that were significant for PHY-FC had a direct negative effect on PHY-FC and an indirect negative effect on FPI, and both of these effects were significant, i.e. the PHY-FC value increased as the COPD_GRD and MRC_SCR values decreased. Many studies have reported that dyspnea affects functional performance, either directly or indirectly through a variety of factors(4,8-11,13,14,17).

The SF_GENER, SF_ENERG and FEV1% indicators that were significant for PHY-FC had a direct positive effect on the PHY-FC and an indirect positive effect on FPI, i.e. the PHY-FC value increased as the FEV1% value, SF_GENER and SF_ENERG scores increased. Although the SF-GENER was considered as a PSY-FC in some studies, it was treated as an indicator of a PHY-FC in the present model since it explained this factor more thoroughly. Mahler *et al.*(33) and Yeh *et al.*(8) found FEV1%to be an effective predictor of functional status. Other studies have found FEV1% and disease severity to have varying direct or indirect effects on functional status (4, 8, 11, 12, 16, 19, 34). Yeh *et al.*(8) found that the SF-ENERG did not directly affect functional performance, but rather that it was affected through dyspnea. The findings of Trendall (35) show that fatigue leads to physical weakness and a decrease in activity. Akyol and Dindar (9) detect a negative correlation between functional performance and fatigue. Although Kapella *et al.*(14)show that there is a significant correlation between functional performance and fatigue among COPD patients, they seen a significant effect from dyspnea and fatigue on functional performance when applied as a hierarchical model.

The HADS-Depression and HADS-Anxiety indicators, which were significant for PSY-FC, had a direct negative effect on PSY-FC and an indirect negative effect on FPI, both of which were significant, i.e. the latent variable for PSY-FC decreased as HADS-Depression and HADS-Anxiety scores increased. Depression and anxiety have been reported to affect functional performance both directly and indirectly in a number of studies (8,9,18,34,36). In general, the present findings on these indicators are in accordance with the literature.

The proposed disease-specific functional status model demonstrates that the independent latent variable of the PHY-FC had a significant positive effect, while the effect of the PSY-FC was insignificant. In general, the rate of functional performance explained via physiological and PSY-FC factors was 65%. Weaver and Narsavage(17)indicate that physiological factors alone can explain only 25% of the functional status of COPD patients, and that psychosocial factors can account for the remainder. The hierarchical models generated by Kapella *et al.*(14)specify functional capacity indicators, disease severity, body fat and symptoms to explain 31% of functional performance. Weldam *et al.*(10) found that 25% of functional performance can be explained by FEV1, smoking status, co-morbidities, dyspnea, age, gender, depressive symptoms, illness perception, proactive coping in regression model.

Conclusions

Functional status is an important factor in the evaluation of quality of life in COPD patients. Therefore, it is extremely important in the clinical field to generate models showing disease-specific functional performance and to examine the factors affecting functional performance using the modeling approach. The COPD-specific functional status model proposed in this study should prove to be an effective and beneficial tool for issues such as treatment maintenance and for the preservation or improvement of patients' quality of life. Investigation of the different indicators affecting physical and psychological factors should be carried out in future studies and, in addition to the expansion of the existing model, functional status models should be developed for specific populations. Lastly, the use of this COPD-specific functional status model is recommended as an additional valuable clinical tool.

Authors' contributions
Study design: SC and EGB.
Data collection: EGB and SB.
Data analysis: SC, EGB and HA.
Manuscript writing: SC, EGB, HA and SB.

Conflicts of interest: The authors declare no conflict of interest.

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