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# PREDICTION OF PULMONARY FUNCTION TEST VALUES IN COPD PATIENTS USING ARTIFICIAL INTELLIGENCE ARCHITECTURE-CLINICAL DECISION SUPPORT SYSTEM

## KOAH HASTALARINDA SOLUNUM FONKSİYON TESTİ DEĞERLERİNİN YAPAY ZEKÂ MİMARİSİ KULLANILARAK TAHMİN EDİLMESİ -KLİNİK KARAR DESTEK SİSTEMİ

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**ABSTRACT**

**Objective:** To develop a model that can predict pulmonary function test (PFT) values in individuals with chronic obstructive pulmonary disease (COPD) using an artificial neural network (ANN).

**Method:** Levenberg-Marquardt algorithm was used. For performance testing, the ANN was trained using the Mean Sequential Error (MSE) method. While age, sex etc. of the individual were input data, PFT value was output data. The data required to test this model were 29 patients diagnosed with COPD, aged between 40 and 70 years, who were referred to Malatya Training and Research Hospital Chest Diseases Polyclinic. A triple cross validation test was used to calculate the performance of the system. The performance parameter was determined using the accuracy parameter.

**Results:** A triple cross validation test was used to calculate performance of system. Accuracy parameter was used as performance parameter. In designed model, average success rates were determined for each PFT value and total average success rate was evaluated as 97.40%.

**Conclusion:** With this system PFT values can be easily determined. It is believed that the system will help in the management of dyspnoea, planning, creating an exercise treatment programme and maintaining quality of life.

**Keywords:** Artificial neural network, Clinical decision support system, COPD.

**ÖZET**

**Amaç:** Yapay sinir ağı (YSA) kullanılarak kronik obstrüktif akciğer hastalığı (KOAH) olan bireylerde solunum fonksiyon testi (SFT) değerinin tahmin edilebileceği bir modelin tasarlanmasıdır.

**Yöntem:** Levenberg-Marquart algoritması kullanılmıştır. Performans testi amacıyla YSA, Ortalama Sıralı Hata (MSE) yöntemi kullanılarak eğitildi. Bireyin yaşı, cinsiyeti vb. gibi özellikleri giriş verileri iken; SFT değeri ise çıkış verisi idi. Bu modeli test etmek için gerekli veri, Malatya Eğitim ve Araştırma Hastanesi Göğüs Hastalıkları Polikliniği'ne başvuran, yaşları 40 ile 70 arasında değişen, KOAH tanısı almış 29 hasta idi. Sistemin performansını hesaplanmasında üçlü çapraz doğrulama testi kullanıldı. Performans parametresi doğruluk parametresi kullanılarak belirlendi.

**Bulgular:** Sistemin performansını hesaplamak için üçlü çapraz doğrulama testi kullanıldı. Doğruluk parametresi performans parametresi olarak kullanıldı. Tasarlanan modelde her SFT değeri için ortalama başarı oranları belirlendi ve toplam ortalama başarı oranı %97,40 olarak değerlendirildi.

**Sonuç:** Bu sistem ile SFT değerleri kolayca belirlenebilecektir. Sistemin; dispnenin yönetilmesinde, planlamada, egzersiz tedavi programının oluşturulmasında ve yaşam kalitesinin sürdürülmesinde yardımcı olacağı düşünülmektedir.

**Anahtar Kelimeler:** Klinik Karar Destek Sistemi, KOAH, Yapay Sinir Ağı.

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*Note: The abstract text of our study was presented at the 8th National Physiotherapy and Rehabilitation Congress.*

## INTRODUCTION

COPD is defined as a permanent, often progressive airflow obstruction associated with chronic respiratory symptoms due to abnormalities of the airways and/or alveoli. COPD is an important public health problem that can be predicted and treated and is the main cause of chronic morbidity in society (GOLD, 2023; Agustí et al., 2023; Agustí, Vogelmeier, Faner; 2020).

Respiratory symptoms are the most prominent feature of COPD and are therefore important in its diagnosis and management (GOLD; 2019). PFTs assess physiological characteristics of the respiratory system. Spirometry is the first step as a screening and diagnostic test for the presence of respiratory disease (Hirai, 2021).

The available literature indicates that the use of PFT is extremely important in monitoring COPD, planning the appropriate treatment programme and determining the effectiveness of treatment interventions. However, it shows that the number of undiagnosed cases of COPD is quite high and that the diagnosis is usually made when the patient's lung function is severely compromised. It is suggested that this situation may be related to the low use of PFTs. It has also been stated that the measurement requires cooperation between the patient and the healthcare professional performing the procedure, and the result obtained depends on technical and personal factors (Zhou et al., 20-22; Miller et al.,2005; Diab et al.,2018).

Many artificial intelligence technologies are used in health sciences (Akalın & Veranyurt, 2020). Computerised clinical decision support systems (CCDSS), which have been increasingly used in recent years, are systems that support clinicians' assessment and decision-making skills. CCDSS not only assist in obtaining relevant information, but also convey information that takes into account the specific clinical context by providing case-specific information and recommendations. Furthermore, such systems do not perform clinical decision making per se, but provide relevant information and analyses that enable the final decision maker to make more informed decisions (Metlay & Armstrong, 2020; Koç et al., 2012). In the literature, architectures such as support vector machines, extreme learning machines and ANNs are commonly used in artificial intelligence-based CCDSS designs. ANNs have the ability to learn, store and identify relationships between data. The use of ANNs has increased in recent years in order to obtain the most accurate and up-to-date information and to develop the most appropriate solutions (Ozdemir et al., 2020).

The aim was to develop a CCDSS that can quickly, accurately and easily measure PFT values in people with COPD. It is envisaged that it can play a role in dyspnoea management, planning and maintaining exercise programme and improving quality of life?

## MATERIALS AND METHODS

### Methodology Used in Evaluating the Hypothesis

In this study, an ANN-based model was developed using real COPD patient data. First of all, the data was normalized (Figure 1). After the normalization process, the data was trained using the ANN method (Figure 2). Age, sex, disease diagnosis time, quality of life, sleep and fatigue level, dyspnea severity, exercise performances and disease symptom severity were used as input data of the designed system in the study, and output data were created for each PFT value.

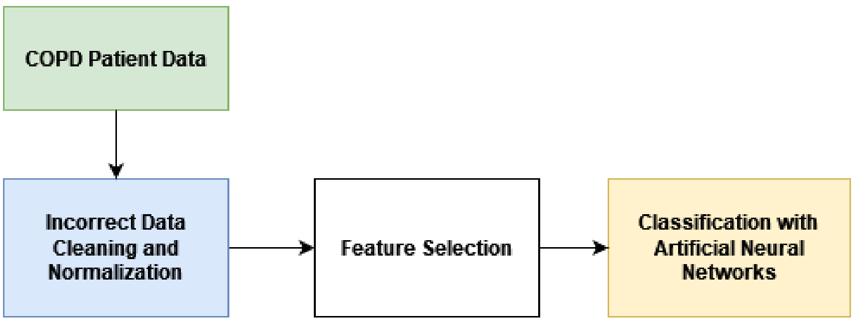


**Figure 1**. Normalization of data

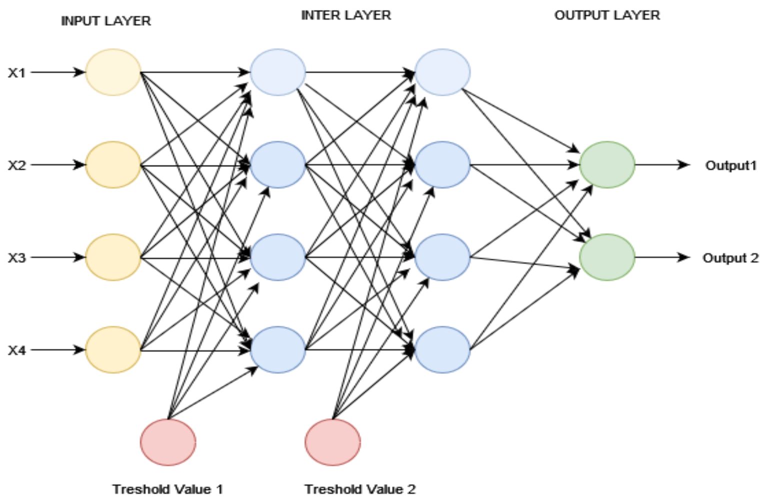


**Figure 2.** ANN model

**Ethical Approval**

The study was conducted in accordance with the Declaration of Helsinki, and informed consent was obtained from all patients before starting the study. Ethical approval was obtained from the Health Sciences Non-Interventional Clinical Research Ethics Committee (2019/377).

**Study Population**

The required data were obtained from 29 clinically stable patients aged 40-70 years with a diagnosis of COPD. Patients with cardiac, neurological, locomotor system disorders, acute respiratory tract infection, and patients who could not adapt to PFT were excluded from the study.

**Data Collection Tools**

**Input Data**

*Demographic and Clinical Characteristics*

Participants' age, sex, income level, body mass index (BMI), duration of diagnosis of the disease, etc. was recorded.

*Quality of Life*

SF-36 (Short Form 36) was used to assess the quality of life of patients. The SF-36 scale allows the evaluation of a person's health status with 8 sub-parameters. Separate scores are taken from each sub-parameter for the scale. Scores vary between 0 and 100, and a higher total score indicates a better quality of life (Koçyiğit et al., 1999; Soyyiğit et al., 2006).

*Sleep Status*

Asthma and COPD Sleep Scale was developed to indicate the effect of the disease on sleep and consists of a total of 7 questions. The questions in the scale are answered according to the Likert scale. The total raw score is obtained by summing the scores obtained from all items. A high score indicates poor sleep quality, and a low score indicates good sleep quality (Pokrzywinski et al., 2009; Ayhan, 2011).

*Fatigue Level*

Participants fatigue levels were evaluated using the COPD and Asthma Fatigue Scale, which consists of 12 items. The items in the scale are answered on a five-point Likert type and the total value varies between 12 and 60 points. The resulting score is converted to a value between 0 and 100 using the formula below. For fatigue status, a single total score is taken from the COPD and Asthma Fatigue Scale and the subdimensions are not evaluated separately. A higher score indicates a higher level of fatigue (Arslan & Öztunç, 2013; Revicki et al, 2010).

*Exercise Performance*

The 6-minute walk test (6MWT) was used to evaluate exercise performance. Patients were asked to walk as fast as possible at their own walking speed for six minutes in a 30meter long corridor with flat and hard floors. The purpose of this test is to measure the maximum distance a person can walk in 6 minutes. At the end of the test, the 6MWT distance was recorded (Ats, 2022; Sağlam et al., 2013).

*Dyspnea Severity*

Modified Medical Research Council Dyspnea Scale A five-step scale was used to determine the patients' dyspnea level. The patient selects the most appropriate level expressing his respiratory distress on a 5-step Likert scale. Scores on this scale range from 0 to 4, with 4 indicating the most severe level of dyspnea (Bestall et al.,1999; Özalevli & Uçan, 2004).

*COPD Assessment Test*
Participants disease symptom severity was assessed using the COPD Assessment Test (CAT). The eight-question test provides information about the grading of the disease, the rating of symptoms, and the impact on the patient's quality of life. Scores obtained from the test range from 0 to 40 points, with a lower score indicating that the disease is least severe and health status is improving (Yorgancıoğlu et al., 2012).

**Output Data**
*Respiratory Function Tests*
Pulmonary function test was evaluated in the sitting position using a spirometer (MasterScreen PFT System; Jaeger, VIASYS Healthcare, Hoechberg, Germany). After at least three acceptable measurements were taken, the best test was selected for analysis. It was repeated 3 times in this way, and the test was accepted as meeting acceptable, reproducible criteria according to the standardization guide of the spirometer. Then Vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak flow rate (PEF), 25-75% of forced expiratory flow (FEF 25-75%) and maximum expiratory flow rate (MEF) 75%, MEF 50% and MEF 25-75% values were recorded (Okur Kuzu et al., 2014).

## RESULTS

The research was carried out on 29 patients. When evaluated, the average age was 62.6±10.02 and 72.4% of the patients were male and 27.6% were female. The average body mass index of the patients was 27.28±4.9 kg/m2.

The sigmoid activation function was used as the activation function in the study. For the performance test, the Levenberg-Marquart algorithm was used as the MATLAB ANN learning method and the ANN was trained using the mean sequential error method. Our sample ANN structure, trained with 11 input layers, 20 middle layers and 1 output layer data for 3000 periods, is shown in Figure 3.

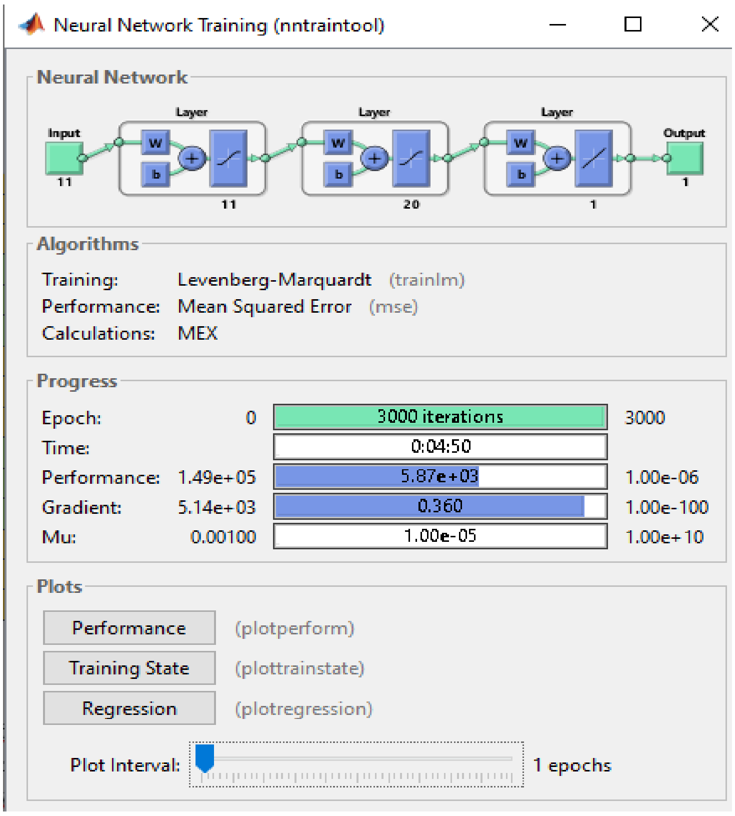


**Figure 3.** Anns model and training parameters

During the training process with ANN, the COPD data obtained from the study was divided into 3 parts; Two sections are used for training, while one section is reserved for testing. This process is repeated for each exit qualification, and success rates by qualification and average success rates on a total basis are presented in Table 1.

**Table 1.** Performance Rates for Output Data

| Qualifications | Partitioned variables | Segmented success rate | Average success rate (%) | Pass rate for all qualifications (Average) |
|---|---|---|---|---|
| VCmax | X1 | 100 | | |
| VCmax | X2 | 100 | **99.3** | |
| VCmax | X3 | 0.98 | | |
| FVC | X1 | 0.869 | | |
| FVC | X2 | 100 | **95.425** | |
| FVC | X3 | 0.99307 | | |
| FEV1% | X1 | 0.9327 | | |
| FEV1% | X2 | 0.96718 | **96.6626** | |
| FEV1% | X3 | 100 | | |
| FEV1%M | X1 | 0.9443 | | |
| FEV1%M | X2 | 0.98144 | **95.8646** | |
| FEV1%M | X3 | 0.9502 | | **97.4030** |
| İC_F% | X1 | 0.9440 | | |
| İC_F% | X2 | 0.96148 | **95.6086** | |
| İC_F% | X3 | 0.96278 | | |
| PEF% | X1 | 0.98337 | | |
| PEF% | X2 | 0.98417 | **98.0646** | |
| PEF% | X3 | 0.9744 | | |
| MEF75% | X1 | 0.9568 | | |
| MEF75% | X2 | 100 | **98.018** | |
| MEF75% | X3 | 0.98374 | | |
| MEF50% | X1 | 100 | | |
| MEF50% | X2 | 100 | **100** | |
| MEF50% | X3 | 100 | | |
| MEF25% | X1 | 100 | | |
| MEF25% | X2 | 100 | **97.684** | |
| MEF25% | X3 | 0.93052 | | |

Vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak flow rate (PEF), 25-75% of forced expiratory flow (FEF 25-75%), maximum expiratory flow rate (MEF)

## DISCUSSION

We aimed to design a CCDSS for the rapid, accurate and easy determination of PFT values of individuals with COPD.

It is known that early markers of COPD development have been investigated by many researchers. It is stated in the literature that prediction and early diagnosis of COPD may encourage patients to quit smoking and enable appropriate timely treatments. It is also predicted that early diagnosis may prevent airway remodeling, improve prognosis, and reduce medical and economic burden (Kwon et al., 2020).

It is known that spirometric measurement is a safe and practical method that is widely used in detecting COPD and making treatment decisions. However, the optimal interpretation strategy for spirometric measurements remains controversial (Csikesz & Gartman, 2014). The system we designed provides average success rates for both each PFT subparameter and the total parameter. We think that these ratios can be widely used in clinical practice, especially in the early diagnosis of COPD, since the spirometric measurement results of the designed model can be evaluated easily and cheaply.

Recently, many commercially available software using algorithms similar to our work have been successfully evaluated (Gawlitza et al, 2019). In a study by Fischer et al., the effectiveness of spirometric measurement in the evaluation of emphysema was compared with the effectiveness of an artificial intelligence-based prototype algorithm obtained using chest CT, and a good correlation was found between them. It has been suggested that the designed system could contribute to the measurement of emphysema severity (Fischer et al., 2020). Ashizawa et al. used ANN in the differential diagnosis of interstitial lung disease in chest radiography (Ashizawa et al., 1999). Another system that can detect emphysema-related changes was designed by Coppini et al., and it was stated that the system could diagnose emphysema with approximately 90% accuracy (Coppini et al., 2007). Bhuvaneswari and colleagues developed a new model for classification of lung diseases using genetic algorithm (Bhuvaneswari et al., 2014). German Gonzalez et al. The study designed a system to determine whether deep learning could detect COPD and predict acute respiratory disease and mortality in smokers, and suggested that this system is a powerful tool (González et al., 2018).

***Limitations***

An important limitation of our study is that the data necessary for the designed model were obtained from a single center. Multicenter studies with larger populations may increase the effectiveness of the designed model.

## CONCLUSION

The results of our study showed that the designed Computer Aided System can determine pulmonary function test parameters quickly, accurately and easily and guide the diagnosis and treatment of COPD patients. We think that this system will help in the early diagnosis of the disease, especially in primary health care institutions. We think that the system will also play a role in managing shortness of breath, planning and continuing an individual-specific exercise program, and improving the individual's quality of life.

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**Conflict of Interest**

There is no conflict of interest.

**Author Contributions**

Plan and desing: F.Ö., B.S.; Data collection: A.A.G., C.İ.; Analysis and comments: A.A.G., C.İ., D.H.; Review and check: F.Ö., B.S.; Writing: F.Ö., B.S.

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