The European Research Journal 2025;11(6):1157-1166 Original Article

DOI: https://doi.org/10.18621/eurj.1777758 *Chest Diseases*

Investigation of the potential predictive value of flow-volume curve changes in patients with obstructive sleep apnea syndrome

Fatma Arzu Akkuş[1], Şebnem Yosunkaya[2]

[1]Department of Immunology and Allergy, Konya City Hospital, Konya, Türkiye; [2]Department of Internal Medicine, Division of Pulmonary Diseases, Necmettin Erbakan University, Faculty of Medicine, Konya, Türkiye

ABSTRACT

Objectives: The relationship between pulmonary function tests (PFT) performed while awake and sleep-related breathing disorders is not yet well defined. This study aimed to examine the potential of flow-volume curve abnormalities in assessing both the presence and severity of obstructive sleep apnea syndrome.

Methods: This retrospective study reviewed medical records of patients evaluated for suspected obstructive sleep apnea syndrome (OSAS) between May 2011 and April 2013. Among 141 patients with available PFT, 99 were diagnosed with OSAS, and 42 were normal based on polysomnography results. Patients were classified into OSAS and control groups, and pulmonary function parameters, including flow-volume curve features, were analyzed.

Results: Of the OSAS patients, 80 (80.8%) were male, while 22 (52.4%) males were present in the control group, which consisted of patients not diagnosed with obstructive sleep apnea syndrome. Among pulmonary function test parameters, the ratio of maximal mid-expiratory flow to forced vital capacity (FEF25-75/FVC) was lower in the obstructive sleep apnea syndrome group than in the control group ($P<0.05$). Patients with the sawtooth sign showed significantly higher apnea-hypopnea index, apnea-hypopnea index during rapid eye movement sleep, and total apnea scores ($P<0.05$). The presence of sawtooth signs in the flow-volume loop was useful for identifying more severe cases of obstructive sleep apnea syndrome.

Conclusions: The complex pathophysiology of obstructive sleep apnea syndrome complicates the identification of patients who need polysomnography. Flow-volume curve abnormalities, indicating airway instability in the upper respiratory tract, are common in these patients and may serve as early indicators of obstructive sleep apnea syndrome.

Keywords: Obstructive sleep apnea, sleep apnea, polysomnography, pulmonary function test, flow-volume curve, spirometry

Obstructive sleep apnea syndrome (OSAS), a type of sleep-related breathing disorder (SBD), is characterized by recurrent episodes of complete (apnea) or partial (hypopnea) obstruction of the upper respiratory tract (URT), resulting in sleep fragmentation, increased daytime sleepiness, and typically a reduction in blood oxygen saturation [1]. URT patency maintains the balance between the collapsing ef-

Received: September 4, 2025 **Accepted:** October 8, 2025 **Available Online:** October 14, 2025 **Published:** November 4, 2025

How to cite this article: Akkuş FA, Yosunkaya Ş. Investigation of the potential predictive value of flow-volume curve changes in patients with obstructive sleep apnea syndrome. Eur Res J. 2025;11(6):1157-1166. doi: 10.18621/eurj.1777758

Corresponding author: Fatma Arzu Akkuş, MD., Phone: +90 332 310 50 00, E-mail: arzusmr@hotmail.com

fect of negative intraluminal pressure during inspiration and the activity of dilator muscles in the URT. This balance is highly complex, as it is influenced by several anatomical, mechanical, neuromuscular, and central factors. In OSAS patients, URTs differ significantly from those of healthy individuals, with more than 75% experiencing airway collapse in the retropalatal region. The obstruction is typically not localized to a single level [2].

Factors that reduce the width of the URT or facilitate obstruction increase the susceptibility to OSAS. Risk factors for OSAS include obesity, male gender, and increasing age [3]. Epidemiological studies have reported an OSAS incidence of 24% in men and 9% in women aged 30-60 years [4]. Male gender is an independent risk factor, as men tend to accumulate more fat in the abdomen and neck. Obesity is the most critical factor, with weight gain directly correlating to increased sleep apnea severity. Fat accumulation in the tongue narrows the URT, raising the risk of collapse [3]. Furthermore, SBD have been reported in several congenital and inherited diseases involving structural alterations in the URT and affecting the respiratory control center [4].

The gold-standard diagnostic method for SBD is polysomnography (PSG) [3]. This test, which is performed under the supervision of a trained technician, is both time-consuming and costly. PSG requires the patient to be hospitalized overnight. According to PSG results, stages of sleep should be examined in detail. Therefore, reliable screening tests are needed to identify patients who require PSG, particularly in cases with a high clinical suspicion index.

Spirometry, a non-invasive physiological test, is commonly used as a general respiratory screening tool [5]. Previous studies have reported flow-volume curve abnormalities that suggest airway instability in the URT of OSAS patients [6]. However, the predictive value of spirometric parameters for OSAS diagnosis remains unclear.

This study aimed to investigate whether flow-volume curve abnormalities and pulmonary function test (PFT) parameters differ between OSAS patients and controls, as well as their association with PSG results and clinical significance. In particular, this study provides a focused evaluation of sawtooth sign prevalence and the FEF50/FIF50 ratio - parameters that are not routinely assessed in OSAS patients - to explore their potential utility in clinical screening. In addition to conventional spirometric indices, previous studies have emphasized the potential value of specific parameters such as the FEF25–75/FVC ratio and FEF50/FIF50 ratio, and saw tooth sign in reflecting upper airway instability in OSAS patients [7-10]. Based on this literature, we hypothesized that these parameters, although not routinely assessed in OSAS evaluation, might show measurable differences between OSAS patients and controls and could correlate with PSG-derived severity markers.

METHODS

Study Design

This retrospective cross-sectional study was approved by the Ethics Committee (approval no: 2012-28) in accordance with the principles of the Declaration of Helsinki. The medical records of 196 patients who underwent PSG due to suspected OSAS between May 2011 and April 2013 were reviewed. Patients with a previous diagnosis of OSAS, obstructive lung disease, active smoking status, or incomplete medical records were excluded from the study. All patients had also undergone an ear, nose, and throat (ENT) examination as part of their clinical evaluation. Patients with significant upper airway abnormalities were excluded based on this assessment. Among the remaining patients, 141 individuals with available and complete PFT results were included in the final analysis. These inclusion and exclusion criteria were applied to minimize potential confounding factors affecting spirometry results and to ensure data integrit.

The diagnosis of OSAS was made by a pulmonologist specializing in sleep disorders based on the combination of clinical symptoms and PSG results, following AASM guidelines. Patients with an AHI >5 accompanied by relevant symptoms were diagnosed with OSAS, while those with an AHI ≤5 and no significant symptoms were classified as controls.

Patients' demographics, clinical histories, and laboratory results were obtained from the patient files and electronic medical records. Anthropometric measurements, including body mass index (BMI), neck circumference, and waist circumference, were recorded. BMI was calculated as weight (in kilograms) divided by height (in meters squared). Neck circumference was measured at the widest part of the neck at the level of the cricoid cartilage.

Polysomnography

Our sleep laboratory used a digital polysomnographic system (VIASYS Healthcare GmbH, Leibnizstraβe 7, 97204 Hoechberg, Germany). Electroencephalography (EEG), electrooculography (EOG), and submental electromyography (EMG) recordings were obtained to evaluate sleep. Respiration was monitored using an oro-nasal flowmeter and a thermistor placed in the nose. Thoracic and abdominal movements were recorded with a thoracoabdominal motion sensor. Oxyhemoglobin saturation and heart rate were monitored using a pulse oximeter. Leg motions were recorded by an EMG sensor placed on the anterior tibial muscle of one leg. Scoring of sleep stages was performed manually according to the AASM scoring criteria [11, 12].

Obstructive apnea was defined as a reduction in airflow by ≥90% for a duration of ≥10 seconds with ongoing respiratory effort. Hypopnea, on the other hand, was defined as a reduction in airflow by ≥30% for a duration of ≥10 seconds, accompanied by an oxy-

Table 1. **Demographic, clinical, and polysomnography features of the OSAS patients and the control group**

Parameter	OSAS (n=99)	Control (n=42)	P value*
Demographic and clinical features			
Age (years)	48.41±10.37	44.33±12.66	**0.048**
Height (cm)	169.41±9.83	167.38±10.59	0.274
Weight (kg)	93.89±16.48	83.14±20.01	**0.001**
BMI (kg/m^2)	33.64±9.88	29.93±8.84	**0.038**
Neck circumference (cm)	44.02±13.34	38.78±3.17	**0.013**
Waist circumference (cm)	106.54±12.76	97.04±9.10	**<0.001**
Systolic blood pressure (mm Hg)	133.23±19.42	121.43±10.94	**<0.001**
Diastolic blood pressure (mm Hg)	73.74±12.74	64.29±11.07	**<0.001**
Hemoglobin (g/dl)	14.64±1.58	13.90±1.72	**0.014**
Hematocrit (%)	44.43±4.56	42.19±3.77	**0.006**
PSG results			
AHI total	36.60±24.97	2.24±1.55	**<0.001**
AHI side	26.20±25.29	2.83±5.94	**<0.001**
AHI supine	50.06±30.59	3.49±3.51	**<0.001**
Total apnea	26.40±23.38	0.81±0.97	**<0.001**
Total hypopnea	10.55±8.75	1.42±1.14	**<0.001**
Minimum SaO_2 (%)	73.74±12.10	87.85±3.30	**<0.001**
Mean SaO_2 (%)	88.91±5.08	93.42±1.98	**<0.001**
Duration of <90% SaO_2	40.91±35.69	5.68±13.02	**<0.001**
Duration of REM (%)	10.18±6.91	5.65±6.28	**<0.001**
Sleep efficiency	78.15±13.63	73.58±15.90	0.085

Data are shown as mean±standard deviation. OSAS=Obstructive sleep apnea syndrome, PSG=Polysomnography, AHI=Apnea hypopnea index, Mean SaO_2=Mean oxygen saturation, Min SaO_2=Minimum oxygen saturation, REM=Rapid eye movement.

*Mann-Whitney U test

gen desaturation of ≥3% or arousal.

The Apnea-Hypopnea Index (AHI) value was calculated by dividing the total number of apnea and hypopnea episodes by the total sleep duration (in hours). When the AHI was between 5 and 15, it was classified as mild OSAS, 16-30 as moderate OSAS, and >30 as severe OSAS [4]. The diagnosis of OSAS was established by considering both symptoms and polysomnographic results together.

From the full-night standard polysomnography (PSG) reports of the patients, the following parameters were recorded: total AHI, AHI during the rapid eye movement (REM) sleep stage (AHI REM), AHI in the supine position (AHI supine), total apneas, minimum oxygen saturation (min SaO_2), the lowest value of oxygen saturation during sleep, mean oxygen saturation (mean SaO_2) recorded night long, the mean of oxygen saturation during sleep, and the ratio of the duration with oxygen saturation below 90% to the duration of full-night sleep (ratio of duration of <90% SaO_2) were recorded. Additionally, for all patients, sleep efficiency (SE), defined as the ratio of total sleep duration to the total time spent in bed, and the ratio of the REM sleep stage duration to the total sleep duration (ratio of duration of REM) were also recorded.

Pulmonary Function Test

PFT was performed in the sitting position using a computerized system (Vmax 22, Sensormedics, USA). The patients exhaled into the mouthpiece at normal tidal volume for spirometric maneuvers, followed by deep inhalation and exhalation. The exhalation duration was at least 6 seconds without interruption. Pulmonary function tests were conducted in accordance with the American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines [13]. A technician instructed each patient to perform at least three maneuvers, and the best values were recorded. PFT data were recorded in liters and as a percentage of the expected values based on age, gender, weight, and height.

From the PFT results of the patients, the following parameters were recorded: forced vital capacity (FVC), forced expiratory volume in the 1st second (FEV1), peak expiratory flow (PEF), FEV1/FVC ratio (Tiffeneau ratio), expiratory flow rates (FEF), maximal mid-expiratory flow rate (FEF %25-75), and maximal expiratory flow rates measured at 25% (FEF 25%), 50% (FEF 50%), and 75% (FEF 75%) of FVC exhaled. From the inspiratory curve, the following parameters were estimated and recorded: forced inspiratory volume at 1 second (FIV1), peak inspiratory flow (PIF), forced inspiratory flow at 50% (FIF 50%), and FEF50/FIF50 ratio. The FEF25-75/FVC ratio was derived by dividing the FEF25-75 value by FVC.

Maximal inspiratory and expiratory flow-volume curves were examined for the presence of a sawtooth sign. According to the definition by Sanders and colleagues, the sawtooth sign was determined by the presence of at least three consecutive, periodic fluctuations in the inspiratory and/or expiratory flow-volume curve [14].

Statistical Analysis

Continuous variables were expressed as mean±standard deviation (SD), whereas categorical variables were expressed as numbers and percentages. Normally distributed variables were compared using the Independent Samples t-test, while non-normally distributed variables were compared using the Mann-Whitney U test. Pearson's chi-squared test and Fisher's exact test were used to compare categorical variables. The relationships between PSG parameters and PFT values were analyzed using Spearman correlation analysis. Statistical analyses were performed using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA). A P-value < 0.05 was considered statistically significant.

RESULTS

Demographic, Clinical, and Polysomnography Results

A total of 141 patients who underwent PSG due to suspected OSAS and whose PFT results were obtained were included in the study. Of these patients, 99 were diagnosed with OSAS, while 42 were considered normal. Among the OSAS patients, 80 (80.8%) were male, whereas 22 (52.4%) of the control group were male (P=0.001). OSAS patients had significantly higher age, weight, neck circumference, waist circumference, and BMI compared to the control group (Table 1). There were no significant differences between the groups in terms of the ratio of ex-smokers, smokers, and smoking-naive individuals.

PSG findings were within normal limits in the control group, while the OSAS group showed signif-

Table 2. **PFT parameters of the OSAS patients and the control group**

PFT parameters	OSAS (n=99)	Control (n=42)	P value
FEV1 (L)	3.40±1.10	3.41±1.10	0.946
FVC (L)	4.19±1.34	4.17±1.47	0.940
FIV1 (L)	3.38±1.19	3.22±1.02	0.456
FEF50 (L/sec)	4.33±1.74	4.40±1.25	0.834
FIF50 (L/sec)	4.41±1.73	3.96±1.70	0.155
PEF (L/sec)	8.16±6.48	7.14±2.60	0.324
PIF (L/sec)	4.73±1.74	4.31±1.67	0.188
FEV1/FVC (%)	81.10±7.90	83.14±5.44	0.129
FEF50/FIF50 ratio	1.15±0.92	1.21±0.37	0.721
FEF25-75/FVC ratio	0.87±0.30	2.55±1.62	**<0.001**

Data are shown as mean±standard deviation. OSAS=Obstructive sleep apnea syndrome, PFT=Pulmonary function test, FEV1=Forced expiratory volume in the 1st second, FVC=Forced vital capacity, FIV1=Forced inspiratory volume in the 1st second, FEF50=Maximal expiratory flow rates 50%, FIF50=Maximal inspiratory flow rates 50%, PEF=Peak expiratory flow, PIF=Peak inspiratory flow, FEF25-75=Maximal mid-expiratory flow rate

*Mann-Whitney U test

icant abnormalities. Group differences in PSG parameters are summarized in Table 1.

Pulmonary Function Test Results

In Table 2, PFT parameters were compared between the two groups. The FEF25-75/FVC ratio was significantly lower in the OSAS patients compared to the control group ($P<0.001$). Sawtooth signs were observed in 4 OSAS patients and 2 controls; however, this difference was not statistically significant due to the small sample size.

Correlation Between PSG Parameters and Spirometry Results

In OSAS patients, correlation analysis revealed that total hypopnea count was significantly negatively associated with FEV1, FVC, FIV1, FEF50, FIF50, and PEF ($P<0.05$). Total apnea count showed a significant positive correlation with PEF ($P<0.05$). Minimum SaO_2 levels correlated positively with FEV1, FVC, FIV1, and FEF50, whereas mean SaO_2 was only positively correlated with FEF50 ($P<0.05$). Additionally, the duration of time with oxygen saturation below 90% was negatively correlated with FEV1, FVC, FIV1, and FEF50 values. These results are summarized in Table 3.

Comparison of OSAS Patients with and without Sawtooth Sign

In OSAS patients with a sawtooth sign, AHI total, AHI REM, AHI side, and total apnea were higher compared to those without a sawtooth sign. Mean SaO_2, however, was significantly lower in OSAS patients with a sawtooth sign than in those without (Table 4).

Comparison of OSAS Patients with and without FEF50/FIF50 > 1

Forty-six (46.5%) of the OSAS patients had an FEF50/FIF50 > 1, whereas 30 out of 42 individuals (71.4%) in the control group had this value. A comparison between OSAS patients with and without an FEF50/FIF50 > 1 is summarized in Table 5.

DISCUSSION

In this study, no significant differences were observed in PFT parameters between OSAS patients and the control group, except for the FEF25-75/FVC ratio, which was significantly lower in OSAS patients (0.87±0.30) compared to controls (2.55±1.62). AHI, AHI REM, AHI side, and total apnea values of the

Table 3. Correlation between PSG parameters and PFT values in patients with OSAS

PSG results	PFT values									
	FEV1 (L)	FVC (L)	FIV1 (L)	FEF50 (L/sec)	FIF50 (L/sec)	PEF (L/sec)	PIF (L/sec)	FEV1/FVC (%)	FEF50/FIF50 ratio	FEF25-75/FVC ratio
	r	r	r	r	r	r	r	r	r	r
AHI total	-0.028	-0.019	-0.028	0.009	-0.069	0.117	-0.024	0.035	0.041	0.017
AHI side	-0.129	-0.127	-0.129	-0.075	-0.104	-0.003	-0.075	0.027	0.007	0.008
AHI supine	0.077	0.098	0.077	0.094	-0.078	0.168	-0.040	0.044	0.110	0.044
Total apnea	0.052	0.054	0.052	0.077	-0.022	0.208*	0.004	0.031	0.038	0.017
Total hypopnea	-0.295*	-0.269*	-0.295*	-0.237*	-0.210*	-0.244*	-0.177	0.009	0.005	0.017
Min SaO_2 (%)	0.307*	0.291*	0.307*	0.236*	0.170	0.121	0.173	0.021	0.066	0.032
Mean SaO_2 (%)	0.188	0.149	0.188	0.225*	0.092	0.035	0.103	0.117	0.108	0.139
Duration of <90% SaO_2	-0.214*	-0.183	-0.214*	-0.203*	-0.100	-0.079	-0.104	-0.098	-0.074	-0.112
Duration of REM (%)	0.130	0.120	0.130	0.161	0.066	0.165	0.065	0.112	0.090	0.105
Sleep efficiency	0.046	0.040	0.046	0.073	0.012	0.075	-0.008	0.059	0.003	0.058

OSAS=Obstructive sleep apnea syndrome, PFT=Pulmonary function test, PSG=Polysomnography, FEV1=Forced expiratory volume in the 1st second, FVC=Forced vital capacity, FEV1: Forced expiratory volume in the 1st second, FEF50=Maximal expiratory flow rates 50%, FIF50=Maximal inspiratory flow rates 50%, PEF=Peak expiratory flow, FEF25-75=Maximal mid-expiratory flow rate, PIF=Peak inspiratory flow, AHI=Apnea hypopnea index, REM=Rapid eye movement, Mean SaO_2=Mean oxygen saturation, Min SaO_2=Minimum oxygen saturation

*r=Spearman correlation coefficient; $P<0.05$

OSAS patients with sawtooth signs were determined to be significantly higher than those without sawtooth signs. The presence of sawtooth signs in the OSAS patients was found to be beneficial in indicating severe OSAS. Furthermore, correlation analysis also demonstrated significant associations between specific PFT parameters and hypopnea and desaturation indices in OSAS patients.

Alterations in the URT seen in OSAS may be reflected in PFTs performed while awake. A previous study showed that the quantitative flow-volume curve standard has high sensitivity and specificity in detecting upper airway obstruction [15]. Notably, a FEF50/FIF50 ratio >1 and the sawtooth pattern observed in the flow-volume curve were both strongly associated with OSAS, indicating URT obstruction and tissue vibration [6, 16]. In a study of 138 OSAS patients, 26.1% had a FEF50/FIF50 ratio >1. No significant differences in age, BMI, AHI, desaturation, or standard PFT parameters were found between patients with and without a FEF50/FIF50 ratio >1 [7]. In our study, while the FEF50/FIF50 ratio did not differ significantly between OSAS patients and controls, a noteworthy distinction emerged within the OSAS group itself. OSAS patients with a ratio >1 exhibited significantly lower inspiratory flow values (PIF and FIV1) compared to those with a ratio ≤1. Additionally, patients with a lower FEF50/FIF50 ratio ≤1 had significantly reduced FEF25-75/FVC and FEV1/FVC ratios, suggesting both small airway dysfunction and potentially greater upper airway resistance. These findings indicate that while the FEF50/FIF50 ratio may offer insights into upper airway resistance, its utility as a predictor of OSAS severity remains limited.

The FEF25-75/FVC ratio has been suggested to reflect small airway function and possibly disproportionate development between the pulmonary parenchyma and airways, which may be associated with increased upper airway resistance [17]. Previous studies have linked a low FEF25-75/FVC ratio to airway hypersensitivity and to a higher prevalence of OSAS in patients with unstable asthma or obesity [8, 18]. While some reports have found no direct correlation between this ratio and PSG parameters [19], our findings demonstrated a significant decrease in the FEF25-75/FVC ratio among OSAS patients compared to controls. This reduction may reflect elevated upper airway collapsibility or resistance, potentially related

Table 4. Demographic features, PFT parameters, and PSG results of the OSAS patients with and without the sawtooth sign

Variables	Those with the sawtooth sign (n=4)	Those without the sawtooth sign (n=95)	P value*
Age (years)	49.50±4.45	48.37±10.55	0.832
BMI (kg/m^2)	32.77±5.15	33.61±10.04	0.859
FEV1 (L)	2.95±0.98	3.42±1.11	0.378
FVC (L)	3.45±1.08	4.22±1.35	0.263
FEV1/FVC ratio	84.00±6.61	80.97±7.95	0.457
PEF (L/sec)	6.16±1.18	8.23±6.60	0.531
FEF50 (L/sec)	3.85±1.60	4.36±1.75	0.557
FIF50 (L/sec)	3.05±1.31	4.40±1.73	0.110
FEF50/FIF50 ratio	1.44±0.97	1.19±0.92	0.524
FEF25-75/FVC ratio	0.97±0.27	0.86±0.30	0.492
AHI total	64.27±29.84	35.43±24.24	**0.023**
AHI REM	78.47±30.37	32.66±25.09	**0.001**
AHI supine	69.65±39.67	49.24±30.14	0.193
AHI side	60.95±37.83	24.74±23.82	**0.004**
Total apnea	56.37±27.73	25.11±22.46	**0.008**
Mean SaO_2 (%)	84.00±8.40	89.12±4.85	**0.048**
Min SaO_2 (%)	64.75±15.84	74.12±11.87	0.130

OSAS=Obstructive sleep apnea syndrome, PFT=Pulmonary function test, PSG=Polysomnography, BMI=Body mass index, FEV1=Forced expiratory volume in the 1st second, FVC=Forced vital capacity, PEF=Peak expiratory flow, FEF50=Maximal expiratory flow rates 50%, FIF50=Maximal inspiratory flow rates 50%, FEF25-75=Maximal mid-expiratory flow rate, AHI=Apnea hypopnea index, REM=Rapid eye movement, Mean SaO^2=Mean oxygen saturation, Min SaO_2=Minimum oxygen saturation

*Mann-Whitney U test

to increased BMI and reduced pharyngeal muscle tone, both of which are commonly observed in OSAS patients. These findings support the potential utility of this ratio as a supportive indicator of upper airway instability in the context of OSAS.

In this study, correlation analysis revealed significant relationships between total hypopnea and oxygen saturation parameters and spirometric indices that reflect inspiratory and expiratory flow limitations in OSAS patients. Total hypopnea count showed negative correlations with FEV1, FVC, FIV1, FEF50, FIF50, and PEF, suggesting that increased hypopnea burden may be associated with notable impairments in respiratory function. While minimum and mean SaO_2 values showed positive correlations with PFT parameters, the duration of <90% SaO_2 was negatively correlated. These findings support the notion that individuals with better respiratory function may experience less desaturation in the context of OSAS. However, the lack of a significant correlation between AHI and spirometric parameters suggests that PFT may not directly indicate the presence of OSAS but may instead reflect URT instability. Similar findings have been reported in previous studies, where no significant correlation was found between AHI severity and spirometric values such as FEV1 or FVC, despite the presence of pulmonary function abnormalities in OSAS patients [20].

In a previous study, among patients undergoing spirometry for any indication, those with the sawtooth sign were found to have a higher likelihood of being diagnosed with OSA compared to those without the

Table 5. Comparison of demographic features, PFT parameters, and PSG results of the OSAS patients with and without a FEF50/FIF50 >1

Variables	FEF50/FIF50 >1 (n=46)	FEF50/FIF50 ≤1 (n=53)	P value
Age (years)	48.15±10.66	48.65±10.21	0.810
BMI (kg/m^2)	33.03±6.62	34.19±12.14	0.564
FEV1 (L)	3.52±1.07	3.29±1.13	0.292
FVC (L)	4.13±1.32	4.25±1.37	0.640
FEV1/FVC ratio	85.78±4.97	76.86±7.69	**<0.001**
PEF (L/sec)	7.57±2.56	8.70±8.62	0.391
PIF (L/sec)	4.08±1.54	5.31±1.71	**<0.001**
FIV1 (L)	3.09±1.16	3.64±1.17	**0.021**
FEF25-75/FVC ratio	1.06±0.24	0.70±0.24	**<0.001**
AHI total	37.88±25.62	35.43±24.57	0.628
AHI REM	36.38±28.81	32.85±24.86	0.519
AHI supine	53.55±31.35	46.91±29.84	0.283
AHI side	26.27±25.18	26.14±25.62	0.981
Total apnea	27.02±23.43	25.83±23.55	0.804
Mean SaO_2 (%)	89.00±5.41	88.84±4.80	0.881
Min SaO_2 (%)	73.51±12.98	73.96±11.36	0.854

OSAS=Obstructive sleep apnea syndrome, PFT=Pulmonary function test, PSG=Polysomnography, BMI=Body mass index, FEV1=Forced expiratory volume in the 1st second, FVC=Forced vital capacity, PEF=Peak expiratory flow, PIF=Peak inspiratory flow, FIV1=Forced inspiratory volume in the 1st second, FEF25-75=Maximal mid-expiratory flow rate, AHI=Apnea hypopnea index, MeanSaO_2=Mean oxygen saturation, MinSaO_2=Minimum oxygen saturation

*Mann-Whitney U test

sign [10]. Several studies have since explored this association in more detail. In a study examining flow-volume curves of 401 patients who presented with snoring and were investigated for OSAS, apnea was found to be more severe in patients with a sawtooth sign during both inspiration and expiration. Sensitivity and specificity of the sawtooth sign in identifying OSAS have been reported to vary widely, ranging from 29% to 85% and 56% to 95%, respectively [10]. In another study, the FEF50/FIF50 ratio >1 and/or sawtooth sign was observed in 40% of OSAS patients, while these features were absent in the control group. OSAS patients with a sawtooth sign had significantly larger height, weight, and neck circumference, and worse PSG results. However, there were no differences in spirometric parameters between OSAS patients with and without the sawtooth sign [19]. In a study investigating the diagnostic value of the flow-volume curve for OSAS, sawtooth signs were significantly more prevalent in OSAS patients compared to other groups ($P < 0.01$). OSAS patients with sawtooth signs had a higher apnea index and more significant reductions in SaO_2 [21]. Another study found that 12.3% of 138 OSAS patients exhibited sawtooth signs, but no significant differences were observed in age, BMI, AHI, desaturation index, or spirometric parameters between those with and without sawtooth signs [7]. In this study, sawtooth signs were present in 4 OSAS patients and 2 controls. While no significant differences were found between these groups regarding demographic or PFT parameters, OSAS patients with sawtooth signs had significantly higher AHI values, AHI REM, AHI side, and total apnea values, as well as lower mean SaO_2. The small sample size of the subgroup with sawtooth signs (n=4) limits the statistical power and generalizability of these findings. Therefore, the results should be interpreted with caution, and further studies with larger cohorts are needed to validate these observations.

Flow-volume curves and PFT parameters are not reliable screening tools for differentiating OSAS patients, as features like the sawtooth sign and FEF50/FIF50 ratio >1 were also observed in the control group. However, the lower FEF25–75/FVC ratio observed in OSAS patients may reflect increased upper airway resistance or instability. This spirometric finding may be associated with OSAS; however, further prospective studies are required to evaluate its diagnostic utility. Notably, the sawtooth sign appeared to be useful in identifying more severe cases of OSAS.

Strengths and Limitations

This study addresses a relatively underexplored area by investigating the relationship between spirometric parameters and OSAS. Additionally, the use of correlation analyses between PSG findings and PFT parameters strengthens the clinical relevance of our results. Finally, by focusing on commonly used and cost-effective spirometric measurements, this study highlights a potentially accessible adjunct tool in the evaluation of OSAS. However, several limitations should be considered, including the small control group and single-center design, which may affect generalizability. Additionally, the lack of a detailed evaluation of confounding factors and the retrospective nature of the study may influence data accuracy. Although the study had a retrospective design, the relationship between flow-volume curve abnormalities and OSAS remains an underexplored area in the literature. To our knowledge, few studies have evaluated whether these PFT patterns can help predict the severity of OSAS. Therefore, we believe that our findings still provide relevant clinical insight. Further prospective studies with standardized methods are necessary to better understand the relationship between PFT abnormalities and OSAS.

CONCLUSION

Given the complex pathophysiology of OSAS, identifying abnormalities in flow-volume curves may serve as an early indicator of disorders leading to OSAS. This approach can help in determining which patients should undergo PSG, which is time-consuming and costly. We suggest that multi-center studies, involving a larger number of cases and identifying modifying factors, are needed to assess the reliability of changes in flow-volume curves for predicting OSAS in patients.

Ethics Approval and Consent to Participate

This study was approved by the Konya University Meram Faculty of Medicine Non-Interventional Clinical Research Ethics Committee (Decision No.: 2012/28 and dated 02.03.2012). All procedures performed during data collection, review of patient records, and study implementation complied with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its subsequent amendments. Informed consent was waived because of the retrospective nature of the study and the analysis used anonymous clinical data.

Data Availability

All data generated or analyzed during this study are included in this published article. The data that support the findings of this study are available on request from the corresponding author, upon reasonable request.

Authors' Contribution

Study Conception: FAA, ŞY; Study Design: FAA, ŞY; Supervision: FAA, ŞY; Funding: ŞY; Materials: ŞY; Data Collection and/or Processing: FAA; Statistical Analysis and/or Data Interpretation: FAA, ŞY; Literature Review: FAA; Manuscript Preparation: FAA; and Critical Review: FAA, ŞY.

Conflict of Interest

The author(s) disclosed no conflict of interest during the preparation or publication of this manuscript.

Financing

The author(s) disclosed that they did not receive any grant during the conduction or writing of this study.

Acknowledgments

The authors have no acknowledgments to declare.

Generative Artificial Intelligence Statement

The author(s) declare that no artificial intelligence-based tools or applications were used during the preparation process of this manuscript. The all content of the study was produced by the author(s) in accordance with scientific research methods and academic ethical principles.

Editor's Note

All statements made in this article are solely those of the authors and do not represent the views of their affiliates or the publisher, editors, or reviewers. Any claims made by any product or manufacturer that may be evaluated in this article are not guaranteed or endorsed by the publisher.

REFERENCES

1. Griffin W, le Roux CW, Heneghan HM, O'Shea D, Garvey JF. The role of weight management in sleep disordered breathing. Breathe (Sheff). 2025;21(3):250182. doi: 10.1183/20734735.0182-2025.
2. Stanczyk M, McNicholas WT, Pevernagie DA, Riha RL, Ryan S. Management of Adult Obstructive Sleep Apnoea: Many Questions, Not Enough Answers! J Sleep Res. 2025;34(5):e70047. doi: 10.1111/jsr.70047.
3. Lee JJ, Sundar KM. Evaluation and Management of Adults with Obstructive Sleep Apnea Syndrome. Lung. 2021;199(2):87-101. doi: 10.1007/s00408-021-00426-w.
4. Lv R, Liu X, Zhang Y, et al. Pathophysiological mechanisms and therapeutic approaches in obstructive sleep apnea syndrome. Signal Transduct Target Ther. 2023;8(1):218. doi: 10.1038/s41392-023-01496-3.
5. Mohning MP, Krefft SD. Use of Spirometry in Pulmonary Function Evaluation. Clin Chest Med. 2025;46(3):401-412. doi: 10.1016/j.ccm.2025.04.001.
6. Campbell AH, Guy PA, Rochford PD, Worsnop CJ, Pierce RJ. Flow-volume curve changes in patients with obstructive sleep apnoea and brief upper airway dysfunction. Respirology. 2000;5(1):11-8. doi: 10.1046/j.1440-1843.2000.00220.x.
7. Ashraf M, Shaffi SA, BaHammam AS. Spirometry and flow-volume curve in patients with obstructive sleep apnea. Saudi Med J. 2008;29(2):198-202.
8. Parker AL, Abu-Hijleh M, McCool FD. Ratio between forced expiratory flow between 25% and 75% of vital capacity and FVC is a determinant of airway reactivity and sensitivity to methacholine. Chest. 2003;124(1):63-69. doi: 10.1378/chest.124.1.63.
9. Liam CK, Lim KH, Wong CM, Lau WM, Tan CT. Awake respiratory function in patients with the obstructive sleep apnoea syndrome. Med J Malaysia. 2001;56(1):10-17.
10. Bourne MH Jr, Scanlon PD, Schroeder DR, Olson EJ. The sawtooth sign is predictive of obstructive sleep apnea. Sleep Breath. 2017;21(2):469-474. doi: 10.1007/s11325-016-1441-x.
11. Sateia MJ. International classification of sleep disorders-third edition: highlights and modifications. Chest. 2014;146(5):1387-1394. doi: 10.1378/chest.14-0970.
12. Ito E, Inoue Y. [The International Classification of Sleep Disorders, third edition. American Academy of Sleep Medicine. Includes bibliographies and index]. Nihon Rinsho. 2015;73(6):916-923. [Article in Japanese]
13. Graham BL, Steenbruggen I, Miller MR, et al. Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement. Am J Respir Crit Care Med. 2019;200(8):e70-e88. doi: 10.1164/rccm.201908-1590ST.
14. Levent E, Sarıman N. Analysis of obstructive sleep apnea patients with "sawtooth sign" on the flow-volume curve. Sleep Breath. 2011;15(3):357-365. doi: 10.1007/s11325-010-0393-9.
15. Wei D, Wang L, Yu Z, et al. Forced Inspiratory Flow Volume Curve in Patients with Obstructive Sleep Apnea-Hypopnea Syndrome. Int J Clin Med. 2023;14(5):260-273. doi: 10.4236/ijcm.2023.145022
16. Thorve SM, Gupta V, Mandilwar S, Modi N, Prabhudesai P. Spirometry and Flow Volume Loops in Obstructive Sleep Apnea Patients. J Int J Contemp Med Res. 2019;6(12):L5-10. doi: 10.21276/ijcmr.2019.6.12.25
17. Tager IB, Weiss ST, Muñoz A, Welty C, Speizer FE. Determinants of response to eucapneic hyperventilation with cold air in a population-based study. Am Rev Respir Dis. 1986;134(3):502-508. doi: 10.1164/arrd.1986.134.3.502.
18. Yigla M, Tov N, Solomonov A, Rubin AH, Harlev D. Difficult-to-control asthma and obstructive sleep apnea. J Asthma. 2003;40(8):865-871. doi: 10.1081/jas-120023577.
19. Oztürk L, Metin G, Cuhadaroğlu C, Utkusavaş A, Tutluoğlu B. FEF(25-75)/FVC measurements and extrathoracic airway obstruction in obstructive sleep apnea patients. Sleep Breath. 2005;9(1):33-38. doi: 10.1007/s11325-005-0006-1.
20. Mehfooz N, Siraj F, Shabir A, et al. Spirometric abnormalities in patients with sleep-related breathing disorders. J Family Med Prim Care. 2021;10(2):1009-1014. doi: 10.4103/jfmpc.jfmpc_1018_20.
21. Rauscher H, Popp W, Zwick H. Flow-volume curves in obstructive sleep apnea and snoring. Lung. 1990;168(4):209-214. doi: 10.1007/BF02719694.