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Forced Inspiratory Flow Volume Curve in Patients with Obstructive Sleep Apnea-Hypopnea Syndrome

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Abstract

Objective: Obstructive sleep apnea-hypopnea syndrome (OSA) is a disease of obstructive apnea or hypopnea caused by a repeated partial or complete collapse of the upper airway during sleep. The inspiratory part of the flow-volume curve (F-V curve) can be used as an auxiliary means to evaluate upper airway obstruction in adults. This study is to evaluate the ability of the F-V curve to predict the OSA and explore inspiratory indicators related to airway obstruction during sleep. **Methods:** There were 332 patients included in this cross-sectional study, who were accompanied by snoring, daytime sleepiness and other symptoms, with suspicion of OSA. According to the nocturnal polysomnography, the subjects were distributed into mild to moderate OSA group, severe OSA group and non-OSA group. A pulmonary function test was used to collect the subjects' spirometry and F-V curves. **Results:** There was no significant difference in a variety of indices derived from the F-V curve between OSA and normal subjects, including 25% inspiratory flow rate, middle inspiratory flow rate, 75% inspiratory flow rate, peak flow rate, and forced inspiratory flow rate in the first second. The pulmonary function parameters were significantly correlated with the weight, age and sex of the subjects. **Conclusion:** These findings suggest that the inspiratory curve of pulmonary function cannot evaluate the upper airway abnormalities in patients with obstructive apnea-hypopnea syndrome.

Keywords

Apnea-Hypopnea Index, Obstructive Sleep Apnea, Pulmonary Function Test, Inspiratory Flow Volume Curve

1. Introduction

Obstructive sleep apnea-hypopnea syndrome (OSA) is a disease of obstructive

apnea or hypopnea caused by a repeated partial or complete collapse of the upper airway during sleep. Abnormalities of upper airway anatomical structure stenosis, neuromuscular function and central respiratory regulation are important factors for the occurrence of sleep apnea. Sleep-disordered breathing due to disease is caused by the obstruction of the upper thoracic airway, which reduces the cross-section of the airway and causes frequent airflow restriction during sleep. [1] [2] It is believed that the mechanisms leading to airway obstruction on sleep-disordered breathing can be summarized in the following four aspects [3] [4]: abnormal morphology of the upper airway; the function of upper airway opening muscle was abnormal; disorders in respiratory drive and regulation; the awakening threshold is abnormal. [5] [6]

Obstructive sleep apnea-hypopnea syndrome may occur in patients with upper airway obstruction. [7] Spirometry is used to diagnose and evaluate respiratory diseases. Pulmonary function examination has important diagnostic value for upper airway obstruction (UAO). [8] [9] [10] In pulmonary function test (PFT), flow volume loop (FVL) is the most valuable one for clinical application. The subjects were instructed to inhale and exhale with maximum strength. The flow volume curve (F-V curve) provided useful information about lung function and the relationship between lung volume and peak flow rate. In particular, when the F-V curve showed a characteristic plateau-like change, upper airway obstruction was highly suspected. [11] There are many factors that affect lung function parameters, including regional and demographic differences, and gender. Height, weight, age, etc. [9] Therefore, for respiratory disease, the percentage of expected values is commonly used to evaluate patients. [9] [10]

During inspiration, the anatomical airway stenosis will lead to the reduction of inhaled air. When exhaling, positive airway pressure will cause trachea dilation and reduce the severity of obstruction. Therefore, for OSA, inspiratory flow measurement is more accurate than expiratory measurement to reflect the pathophysiological abnormalities of upper thoracic airway obstruction. Indicators measured by spirometers may help to distinguish upper respiratory tract obstruction from other respiratory diseases. [8] [12] [13] The inspiratory part of the F-V curve can be used as an auxiliary means to evaluate upper airway obstruction in adults. [12]

The sleep process of OSA patients is an important part of the upper airway muscle relaxation or airway collapse at night. Snoring may increase the work of breathing and the cost of oxygen, and lead to hypoxia. Considering the decrease in ventilatory regulation observed at rest and the activation of the ventilation system during forced vital capacity testing during the day, it is worth investigating whether there are any changes in the ventilatory response and inspiratory flow of OSA patients. Therefore, the purpose of this research is to evaluate airflow restriction and airway obstruction by investigating the relationship between PFT and indicators of PSG, and to determine whether abnormal upper airway anatomy affects the inspiratory index. Subsequently, we analyze the F-V curve of

PFT in OSA patients during the awake period. We are interested in inspiratory lung function parameters (ILPs) (forced inspiratory volume in 1 second (FIV1), forced inspiratory flow at 50% of the vital capacity (FIF50) and peak inspiratory flow (PIF), etc.) and have researched their effects in multiple studies.

2. Materials and Methods

2.1. Study Subjects

In total 332 consecutive subjects (246 males, 86 females) who without a medical history of lung diseases and an expiratory flow limitation, but who were troubled with were snore to various levels or suspicion of OSA were eligible for this study from September 2019 to April 2022. The following exclusion criteria were used: clinical instability (such as patients with major hemoptysis, cancer, respiratory failure, and hemodynamic instability); history of respiratory infection in the last three weeks; evidence of overlap between sleep snoring and chronic airway diseases; and inability to perform (PFT).

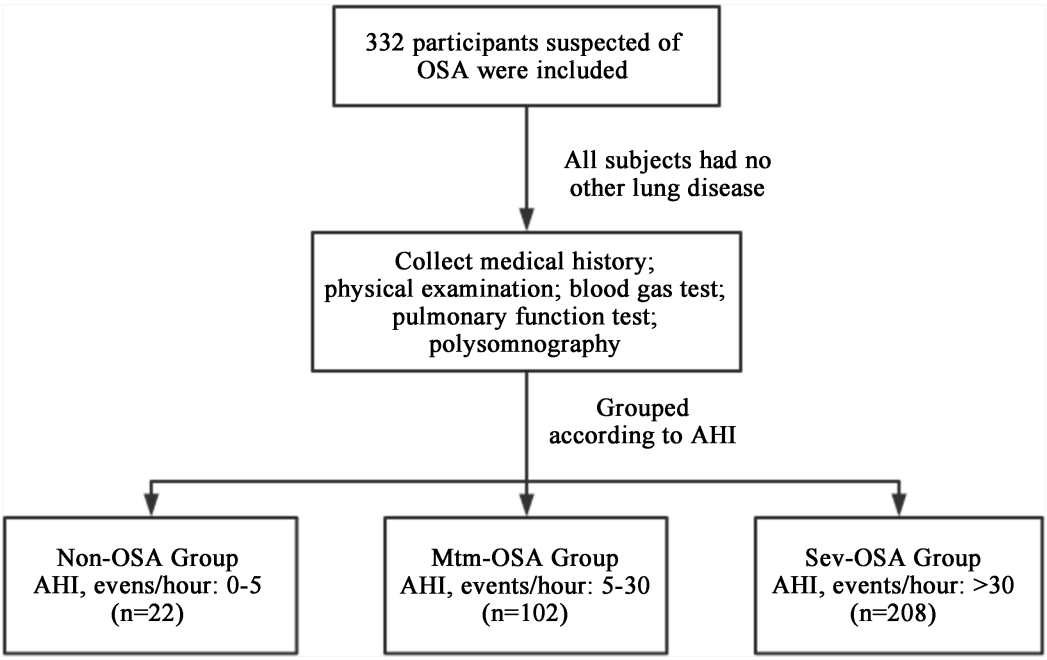
The protocol was approved by the Research Ethics Committee of the General Hospital of Tianjin Medical University under the number IRB2022-WZ-209, and it complied with the current national and international standards. All individuals signed informed consent when they were admitted to the hospital.

2.2. Overnight Polysomnography

All subjects received nocturnal polysomnography (Alice 5 Diagnostic Sleep System; Philips Respironics, Bend, OR, USA), consisting of at-least seven hour monitoring period of electroencephalogram (central and occipital), electromyogram, electrocardiogram (lead II), right and left extra-ocular eye movement, thoracic and abdominal wall movement, air flow, O_2 saturation, end-tidal CO_2 levels, snore volume, bilateral leg movement, and sleep position. All acquired PSG data were digitized and evaluated by the respiratory doctor of the Sleep Medical Center of the General Hospital of Tianjin Medical University. The ratio of the total number of apnea and hypopneas to the total sleep time in hours were calculated to obtain AHI scores. An AHI < 5 was considered as normal or simple snoring, 5 to 15 as mild OSA, 15 to 30 as moderate OSA, and >30 as severe OSA. [14] T90 was defined as the proportion of cumulative sleep time with oxygen saturation below 90% in total sleep time. According to the nocturnal polysomnography, the subjects were distributed into mild to moderate OSA group (Mtm-OSA Group), severe OSA group (Sev-OSA Group) and non-OSA group (**Figure 1**).

2.3. Pulmonary Function Testing

All of the subjects were asked to not use bronchodilators within 24 h prior to spirometric testing. The pulmonary function testing (PFT) (Master screen PFT, Jaeger crop, Hoechberg, Germany) performed were spirometry, body plethysmography, and diffusion capacity for carbon monoxide (DLCO). Participants were examined according to the standards set forth by the American Thoracic



Abbreviations: AHI, apnea-hypopnea index; OSA, obstructive sleep apnea.

Figure 1. Flow chart of the identification of the study population.

Society (ATS). [8] Guide the subjects to inhale or exhale deeply using the strength of their chest and abdomen to avoid respiratory muscle fatigue. At least three flow volume curves were measured, two of which were reproducible, meeting the recommended quality control criteria. The best curve was chosen on the basis of the sum of the best FVC (forced vital capacity) and the best FEV1 (forced expiratory volume in 1 second). The Chinese reference value was used, and the results are presented in terms of the measured value and expressed as percentages of the predicted values. [15] For the inspiratory parameters, at least 5 adequate values were obtained after a slow and maximal expiration. Inspiratory values were calculated using the curve that obtained the best inspiratory effort, *i.e.*, the greatest FIF50%. The best derived inspiratory parameters were further analyzed. All of the measurements were performed by the same person, who also explained the inhalation technique in detail before the test and monitored the technique carefully.

2.4. Demographic Characteristics and Laboratory Indicators

At admission, all participants underwent detailed physical examination and medical history collection, including sex, age, height, weight, waist circumference, neck circumference, medical history, and family medical history, etc. Prior to the test, all of the subjects were evaluated for pharyngeal obstruction on the use of the Friedman staging system. Daytime sleepiness was assessed based on the Epworth sleepiness scale (ESS) score. We collected and recorded the arterial blood gas of subjects (pH, arterial oxygen pressure (PaO_2), arterial carbon dioxide pressure ($PaCO_2$), bicarbonate [HCO_3^-], etc.)

3. Statistical Analysis

All parameters are expressed in mean differences ± standard deviation (x ± s), or median with interquartile range (IQR), or number (percentage), according to the normality test; Comparison of the clinical variables, PFTs, and PSG between subjects without OSA and subjects with sleep apnea in different groups was performed using one-way ANOVA or Kruskal Wallis test; Pearson's chi square test was used to compare the ratios of numerical variables. Calculate the correlation coefficient between pulmonary function parameters and AHI. The receiver operating characteristic (ROC) curve was constructed to study the predictive value of the baseline change percentage of each indicator to reach the diagnostic OSA.

SPSS for Windows (SPSS Inc., Chicago, IL, USA), version 20, was used for the statistical analyses, and GraphPad Prism 8.0 (GraphPad, San Diego, CA, USA) was used to construct the figures. P-value < 0.05 (two-sided) was considered statistically significant.

4. Result

A total of 332 subjects were finally included in the study analysis and grouped according to the AHI index. Baseline data of Clinical characteristics, pulmonary function, and PSG results for all subjects are given in Tables 1-3 respectively.

Table 1. General physiological characteristics and blood gas results of subjects in each group.

Variables	Non-OSA group (n = 22)	Mtm-OSA group (n = 102)	Sev-OSA group (n = 208)	F/X^2	P-Value
Gender, n (male/female)	22 (10/12)	102 (66/36)	208 (170/38)	20.405	0.000*
Age, years	43.64 ± 16.91	48.62 ± 15.13	47.61 ± 13.68	1.091	0.337
Height, cm	170.77 ± 6.72	169.67 ± 8.33	172.07 ± 8.65	2.795	0.063
Weight, kg	80.43 ± 22.09	83.20 ± 14.84	96.55 ± 26.71[ab]	13.718	0.000*
BMI, kg/m^2	27.45 ± 6.98	28.94 ± 4.98	32.51 ± 8.14[ab]	11.305	0.000*
SBP, mmHg	121.45 ± 15.29	125.39 ± 15.50	129.53 ± 18.88	3.309	0.038*
DBP, mmHg	76.96 ± 8.48	84.01 ± 11.81	85.88 ± 13.59	5.054	0.007*
Waist circumference, cm	94.00 ± 25.74	99.81 ± 18.25	108.09 ± 20.78	8.826	0.000*
Neck circumference, cm	39.19 ± 4.53	40.38 ± 4.03	42.90 ± 4.43[ab]	15.845	0.000*
Frideman position (I-II/III-IV)	9/13	36/66	65/143	1.148	0.563
Blood Gas Analysis					
PH	7.40 ± 0.03	7.41 ± 0.02	7.38 ± 0.36	0.241	0.786
PO_2, mmHg	76.88 ± 9.28	78.98 ± 10.95	71.63 ± 10.46[b]	13.171	0.000*
PCO_2, mmHg	39.18 ± 3.31	40.31 ± 6.63	41.19 ± 4.72	1.560	0.212
HCO_3^-, mmol/L	23.44 ± 1.66	24.73 ± 3.01	25.65 ± 4.37[a]	3.385	0.035*
SAO_2, %	97.1 (95.7 - 97.85)	96.9 (96.25 - 97.65)	96.2 (94.6 - 96.95)[b]	20.985	0.004**

Definition of abbreviations: BMI, body mass index; SBP, arterial systolic pressure; DBP, arterial diastolic pressure; Notes: a indicates P < 0.05 compared with non-OSA group; b indicates P < 0.05 compared with mild-moderate OSA group.

Table 2. Flow volume curve of pulmonary function parameters of all participants.

Pulmonary Function Parameters	Non-OSA group (n = 22)	Mtm-OSA group (n = 102)	Sev-OSA group (n = 208)	F	P-Value
Expiratory parameters of flow volume curve					
FVC, L	3.53 ± 1.24	3.33 ± 1.60	3.53 ± 1.33	0.613	0.542
FVC %predicted	97.91 ± 13.42	95.94 ± 20.29	91.67 ± 17.01	2.041	0.132
FEV1, L	2.73 ± 1.29	2.96 ± 1.12	2.97 ± 0.94	0.469	0.626
FEV1 %predicted	94.46 ± 18.29	92.42 ± 22.56	93.54 ± 64.02	0.061	0.984
FEV1/FVC	80.83 ± 9.14	78.52 ± 13.32	80.01 ± 6.82	0.794	0.453
PEF, L/s	11.98 ± 19.66	7.96 ± 2.37	8.47 ± 5.72	2.350	0.097
PEF %predicted, %	94.29 ± 19.58	101.00 ± 22.97	98.55 ± 21.48	0.723	0.487
FEF50, L/s	3.48 ± 1.85	3.30 ± 2.18	3.43 ± 1.71	0.166	0.847
FEF50, %	80.73 ± 31.19	80.95 ± 35.74	78.82 ± 29.62	0.128	0.880
Inspiratory parameters of flow volume curve					
FIV1, L	3.27 ± 1.01	3.24 ± 0.98	3.35 ± 1.07	0.414	0.661
FIV1/FVC	90.74 ± 13.45	91.86 ± 11.15	91.87 ± 11.08	0.103	0.902
PIF, L/s	4.87 ± 1.87	4.41 ± 1.53	4.49 ± 1.74	0.619	0.539
PEF/PIF, %	0.67 (0.54 - 1.13)	0.76 (0.44 - 0.99)	0.85 (0.58 - 1.14)	4.650	0.098
FIF75, L/s	3.81 ± 1.71	3.46 ± 1.46	3.57 ± 1.53	0.537	0.585
FIF50, L/s	4.50 ± 1.87	4.13 ± 1.55	4.19 ± 1.69	0.437	0.647
FIF25, L/s	4.30 ± 1.79	3.93 ± 1.42	4.02 ± 1.59	0.492	0.612
FEF50/FIF50, %	0.80 ± 0.48	0.80 ± 0.61	0.90 ± 0.49	1.261	0.285
In Area, L^2/s	13.95 ± 7.68	12.89 ± 7.62	13.70 ± 8.28	0.391	0.677
Ex Area/In Area, %	1.07 ± 0.45	1.18 ± 0.56	1.19 ± 0.45	0.658	0.519
Pulmonary diffusion function					
DLCO, mmol/min/kPa	7.13 ± 2.04	7.45 ± 2.08	7.74 ± 1.85	1.125	0.326
DLCO% predicted	74.33 ± 14.25	76.27 ± 16.70	80.85 ± 13.86	1.544	0.216

Definition of abbreviations: FVC, forced vital capacity; FEV1, forced expiratory volume in 1 second; PEF, peak expiratory flow; FEF50: forced expiratory flow at 50% of FVC; FIV1, forced inspiratory volume in 1 second; PIF, peak inspiratory flow; FIF75, forced inspiratory flow at 75% of FVC; FIF50, forced inspiratory flow at 50% of FVC; FIF25, forced inspiratory flow at 50% of FVC; FEF50/FIF50, ratio of FEF50 to FIF50; In Area, area of Inspiratory part of flow volume curve; Ex Area, area of expiratory part of flow volume curve; DLCO, diffusing capacity of the lungs for carbon monoxide.

There were more men in severe OSA group, with higher BMI and thicker waist circumference and neck circumference (Table 1). No difference between groups in evaluating the degree of pharyngeal stenosis according to the Frideman. The daily blood gas indicators of participants in each group showed that the oxygen saturation and partial pressure of OSA patients decreased compared with the normal group, and the severe OSA decreased more significantly ($p < 0.01$). The

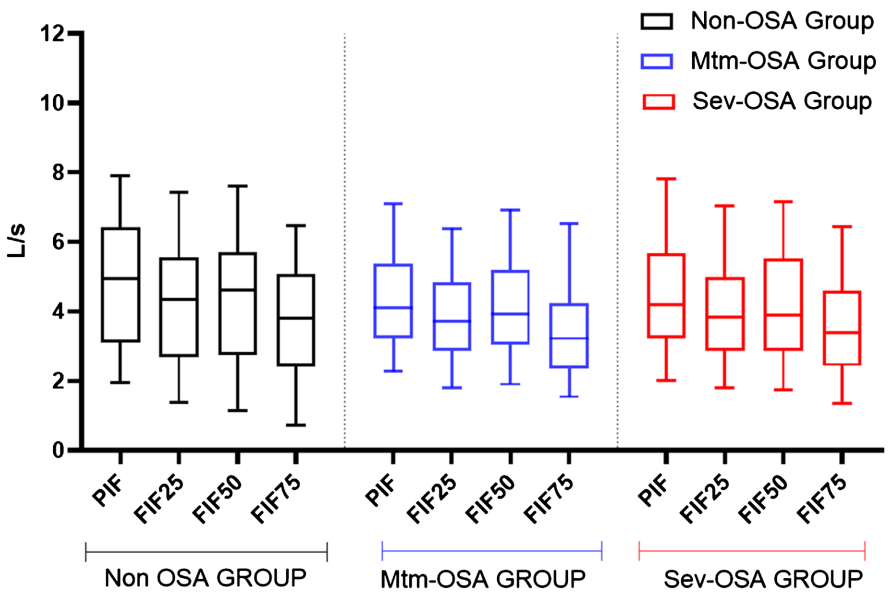
difference between the above groups was statistically significant, and HCO_3^- also changed to varying degrees ($p < 0.05$).

The data of pulmonary function flow volume curve are shown in Table 2 and Figure 2. The inspiratory flow velocity indexes in non-OSA group, including PIF, forced inspiratory flow at 75% of FVC (FIF75), FIF50, forced inspiratory flow at 25% of FVC (FIF25), and the area of inspiratory part of flow volume curve

Table 3. Polysomnographic characteristic of the study population.

Polysomnography	Non-OSA group (n = 22)	Mtm-OSA group (n = 102)	Sev-OSA group (n = 208)	F	P-Value
AHI, events/h	2.5 (1.45 - 3)	17.2 (10.1 - 23.8)[a]	67.5 (47.8 - 78.73)[a,b]	267.102	0.000**
ODI, events/h	1.7 (0.8 - 2.85)	14 (7.40 - 19.7)[a]	62.2 (43.03 - 89.65)[a,b]	178.747	0.000**
AI, events/h	0.3 (0 - 0.8)	1.9 (0.4 - 5.78)[a]	37.2 (12.33 - 64.33)[a,b]	153.664	0.000**
HI, events/h	1.65 (0.9 - 2.9)	12.55 (7.88 - 18.28)[a]	19.95 (6.5 - 34.7)[a,b]	30.152	0.000**
SpO_2mean, %	96.00 (95.00 - 97.00)	95.00 (94.00 - 96.00)	92.00 (89.00 - 94.00)[a,b]	106.023	0.000**
SpO_2min, %	91.00 (89.00 - 92.00)	85.00 (81.00 - 87.25)[a]	69.00 (57.00 - 78.00)[a,b]	160.015	0.000**
Arl, events/h	5.55 (3.68 - 9.55)	13.8 (8.1 - 18.2)[a]	37.7 (22.3 - 55.25)[a,b]	15.190	0.000**

Definition of abbreviations:: AHI, apnea-hypopnea index; ODI, oxygen desaturation index; AI, apnea index; HI, hypopnea index; SpO_2mean, mean percutaneous oxygen saturation; SpO_2min, minimum percutaneous oxygen saturation; Arl, arousal index. Notes: a indicates $P < 0.05$ compared with non-OSA group; b indicates $P < 0.05$ compared with mild-moderate OSA group; *, a statistical difference between representative groups ($P < 0.05$); *, a statistical difference between representative groups ($P < 0.01$).



Abbreviations: PIF, peak inspiratory flow; FIF75, forced inspiratory flow at 75% of FVC; FIF50, forced inspiratory flow at 50% of FVC; FIF25, forced inspiratory flow at 50% of FVC.

Figure 2. Inspiratory flow rate at different stages of each group. The inspiratory flow velocity indexes in non-OSA group, including PIF, FIF75, FIF50, FIF25, and In Area were higher than those in OSA patients, but there was no statistical difference.

(In Area), were higher than those in OSA patients, but there was no statistical difference. The ratio of peak expiratory flow to peak expiratory flow (PEF/PIF) and ratio of forced expiratory flow at 50% of FVC to forced inspiratory flow at 50% of FVC (FEF50/FIF50) increased in sev-OSA Group, which also indicated that the inspiratory flow rate was limited.

The study data showed that the inspiratory parameters of pulmonary function had no positive effect on the severity grading of OSA (**Figure 3**). We tried to analyze other factors that affect pulmonary function indicators, and found that age, gender, weight and inspiratory parameters are all related. The results showed that PIF was negatively correlated with the age ($r = -0.059$, $P < 0.001$) and neck circumference ($r = 0.044$, $P < 0.032$), and positively correlated with the body weight ($r = 0.012$, $P < 0.0013$).

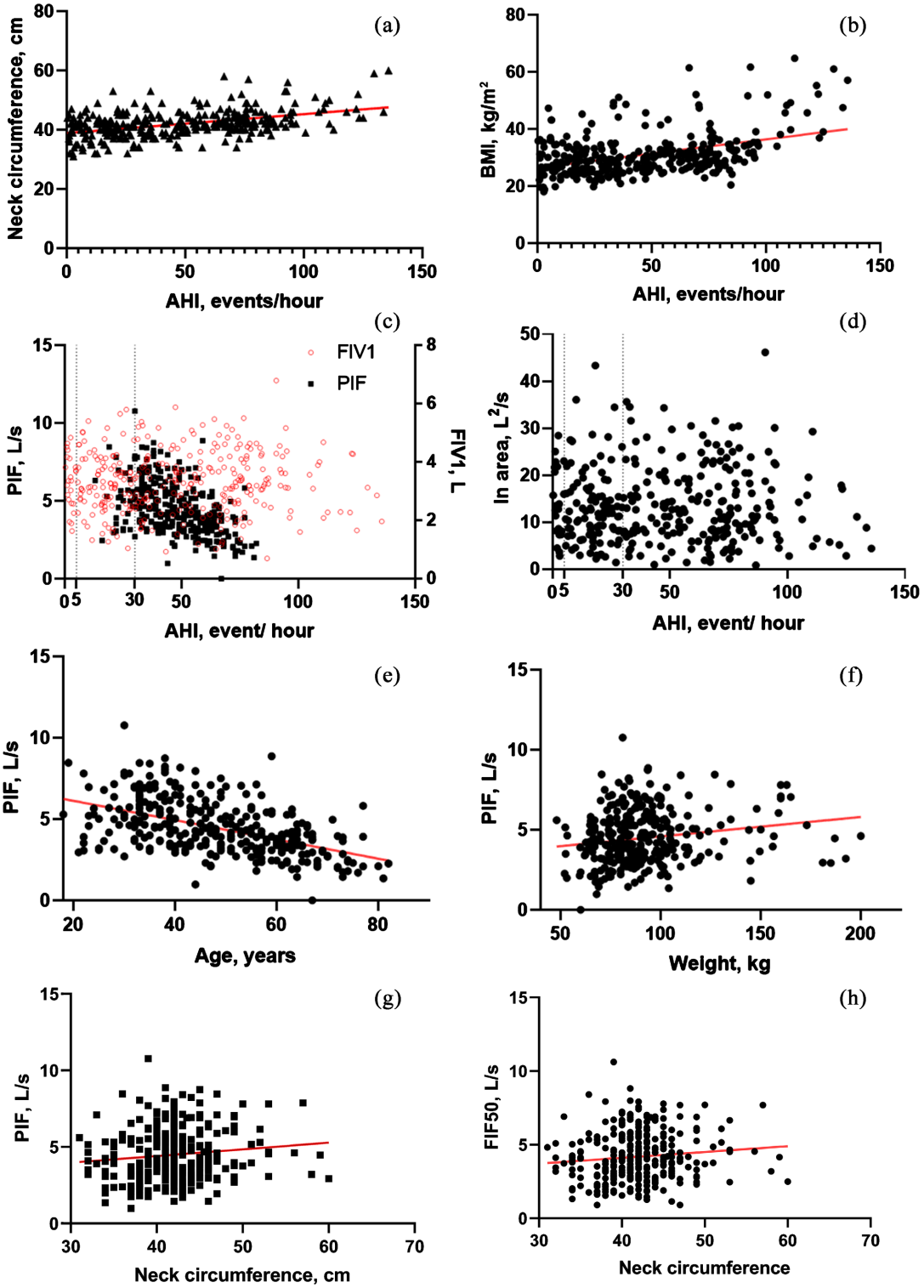
According to the neck circumference, arterial partial pressure of oxygen and BMI, the ROC curve was drawn to diagnose OSA. The results showed that the combined diagnostic ability of the three indicators was better than that of the single indicator (**Figure 4**).

PSG showed that the data of the overall participants were reliable. According to different AHI groups, the minimum percutaneous oxygen saturation (SpO_2min), mean percutaneous oxygen saturation (SpO_2mean), arousal index and oxygen desaturation index (ODI) of patients with severe OSA were more serious than those of the other two groups, and the difference was statistically significant. No positive results of pulmonary function parameters among the three groups (**Table 3**).

5. Discussion

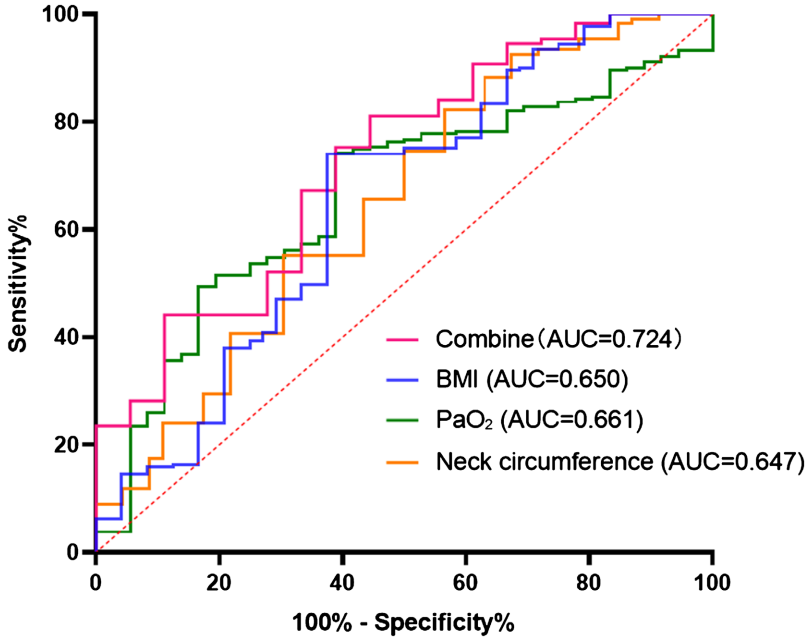
The study confirmed that the daytime pulmonary function test of OSA patients did not find the evidence of upper airway obstruction, even if the patients had severe apnea and hypoxia events during sleep. Stenosis of upper airway is an important factor in OSAHS. The increase of upper airway soft tissue with or without maxillofacial anatomical structure abnormality due to obesity, upper airway anatomy abnormality and other reasons can make the airway cross-section of OSAHS patients smaller, their airways are narrower and longer, and they are more likely to collapse than those without apnea. Among them, the stenosis of pharyngeal cavity anatomical structure is involved in airflow limitation during sleep. They rely heavily on the compensatory activation of the airway expander to maintain smooth airflow when awake. [1] [16] Liliana's research shows that the quantitative standard of flow curve has high sensitivity and specificity in detecting upper airway obstruction. [17] There are different views on the value of sawtooth wave as a screening test for OSA. [18]

In OSA patients, we have investigated the influence of the preceding expiratory, no significant difference was found among the groups. The inspiratory parameters of pulmonary function in OSA patients were not significantly different from those in simple snoring, and were not significantly related to the AHI and



Abbreviations: FIV1, forced inspiratory volume in 1 second; PIF, peak inspiratory flow; In Area, area of Inspiratory part of flow volume curve.

Figure 3. Linear relationship among variables. AHI was positively correlated with neck circumference and BMI (a) and (b); PIF, FIV1, In Area and AHI have no linear correlation (c) and (d); Negative correlation between PIF and age (e); Negative correlation between PIF and body weight (f); Neck circumference is positively correlated with PIF and FIF50 (g) and (h).



Abbreviations: PaO_2, arterial partial pressure of oxygen; BMI, body mass index; OSA, obstructive sleep apnea.

Figure 4. Receiver operating characteristic (ROC) curve analysis of BMI, neck circumference, PaO_2 to recognize OSA patients. The combination of three indicators has more advantages for OSA diagnosis.

the lowest oxygen saturation obtained from PSG. Because there is no clear standard for the predicted value of the inspiratory parameters at present, it is impossible to compare the percentage of the estimated value of people of different ages, genders, heights and weights, so the specificity of various indicators of the inspiratory curve for disease diagnosis is reduced. As the gold standard of diagnosis, PSG is an indispensable means of OSA examination.

Although there is no significant difference in inspiratory flow rate among patients with OSA of different degrees, we still have some interesting findings. The neck circumference of OSA patients is consistent with the inspiratory parameters, which is consistent with our hypothesis. The increase of neck circumference to some extent indicates the accumulation of neck fat, which further blocks the opening of the upper airway. When the subjects inhaled with great force, PIF, FIF50, and other indicators decreased to varying degrees. The result of our data is that each index of inspiratory flow is related to sex, age and weight. The study indicated that BMI was a clinical predictor of the AHI. The correlation between BMI and OSA was complex. Most of the literature in the past demonstrated that an increase in BMI was related to an increase in AHI. [19] [20] The result of our data is that the severity of OSA patients is closely related to BMI, and each index of inspiratory flow is related to gender, age and weight. It may be more important to use predicted values to predict upper airway obstruction in OSA.

Most individuals who are severely obese can maintain blood gas homeostasis through augmentation of alveolar ventilation and carbon dioxide (CO_2) output.

[21] [22] Our study found that the decrease of daytime arterial partial pressure of oxygen and the low level of oxygen saturation were related to the severity of OSA.

On the other hand, it has been reported that the degree of severity of OSAS was thought to be mostly associated with the sleep time spent in the supine position. Rissanen *et al.* showed that supine position is related to the duration of hypoventilation and apnea in different sleep periods, and it is a risk factor for aggravating OSA. [23] [24] Upper airway collapsibility was greater in supine position compared to lateral position. Suzuk *et al.* treated OSA by correcting sleep state in supine position. In supine position, the tongue base narrowed the upper airway by the effect of gravity. Therefore, respiratory events were seen less in side position. The standard pulmonary function test requires the patient to take the upper body upright position for forced inspiration and breathing, which is very different from the position during sleep at night. [8] It cannot be ruled out that the position has an impact on the pharyngeal anatomy. We did not find any abnormality of the inspiratory ring in OSA patients, including the reasons for posture. Compared with normal subjects, OSA patients have greater muscle tension in the upper airway, which is considered necessary to maintain the smooth airway with OSA stenosis. [4] [25] With the loss of upper airway expander activity at the beginning of sleep, the anatomical stenosis of OSA makes the upper airway particularly vulnerable to this loss of expander activity during sleep. [26] [27] This is consistent with the assumption that the increase in the degree of upper airway stenosis during sleep is sufficient to cause abnormal flow volume curves. These mechanisms may explain why flow restriction occurs during sleep, but not during waking. [28] But forced vital capacity was done while the participants were awake.

The limitations of this research are pointed out. Firstly, this is a cross sectional study, therefore, we cannot make any certain conclusion about the correlation between these factors and AHI. In addition, the patients studied were from only one sleep disorder center, which could have resulted in sampling bias. Larger, multicenter studies are required to further investigate the risk factors for OSA.

6. Conclusion

In this study, we tried to assess airflow limitation by means of physical examination during the awake period and PSG, and assumed that the abnormal parameters of the F-V curve of the spirometer in most patients could be attributed to the upper airway structure and airway expansion muscle response. Unfortunately, we have not found any effective parameters that can predict the occurrence of OSA from the pulmonary function test. The inspiratory parameters of lung function are closely related to many factors. It is hoped that more studies will be conducted in the future to propose reference standards for inspiratory predictive values of normal people, which will play a more effective role in evaluating clinical diseases. Positive results may be found as a percentage of expected values.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Ethics Statement

The study protocol was approved by the Medical Ethics Committee of Tianjin Medical University General Hospital (No. IRB2022-WZ-209), and the procedures followed were in accordance with the Helsinki Declaration in 1995, as revised in 2013. The information of the included subjects was extracted from the electronic medical records of the sleep center, and their personal identities were kept anonymous.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work. Jie Cao is co-correspondent.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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