Am J Transl Res 2026;18(1):691-704
www.ajtr.org /ISSN:1943-8141/AJTR0168669

Original Article

Weight loss improves the short-term efficacy of surgical treatment for obstructive sleep apnea

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Received September 8, 2025; Accepted December 12, 2025; Epub January 15, 2026; Published January 30, 2026

Abstract: Objective: To investigate the effect of weight loss on short-term efficacy of patients with obstructive sleep apnea (OSA) after surgery. Methods: The case data of 200 OSA patients who received surgical intervention and underwent low-calorie diet and exercise to lose weight after operation were retrospectively analyzed. The data of efficacy, polysomnography (PSG), Calgary Sleep Apnea Quality of Life Index (SAQLI), Epworth Somnolence Scale (ESS), and snoring score (SS) before and after operation were analyzed between the loss weight group (LG) and constant weight group (CG). Following the identification of predictors of treatment efficacy by univariate analysis and Logistic regression modeling, a nomogram was developed and validated for performance evaluation. Results: Compared to CG, the overall effectiveness (91.67% v.s. 67.97%, P<0.001), apnea-hypopnea index (AHI; 36.57±17.20 events/hour v.s. 50.85±18.50 events/hour; P<0.001), lowest arterial oxygen saturation (LSaO2; 0.84±0.11 v.s. 0.77±0.09; P<0.001), the percentage of total recording time with arterial oxygen saturation below 90% (TS90%; 18.07±11.26% v.s. 24.00±13.98%; P<0.001), the total score of SAQLI (5.44±0.69 score v.s. 5.03±0.71 score; P<0.001), ESS (8.96±4.68 score v.s. 12.13±4.27 score; P<0.001), and SS (4.97±1.62 score v.s. 5.91±1.54 score; P<0.001) in LG were significantly improved after surgery (P<0.01). According to univariate analysis and multivariable analysis, body mass index (BMI; OR=1.334, 95% CI: 1.134-1.569, P=0.001), neck circumference (NC; OR=1.260, 95% CI: 1.048-1.515, P=0.014), dietary management (OR=0.327, 95% CI: 0.151-0.710, P=0.005), and sustained exercise (OR=0.313, 95% CI: 0.138-0.709, P=0.005) exert independent effects on OSA treatment. Using these variables, a nomogram for forecasting unsuccessful OSA treatment was constructed. When subjected to 1000 Bootstrap resampling tests, the model achieved a C-index of 0.805 (95% CI: 0.721-0.884), demonstrating strong model discrimination. Calibration curves indicated accurate prediction performance in the low and intermediate risk categories. Conclusion: Effective control of body weight after surgery can significantly improve the short-term efficacy and quality of life of patients with OSA.

Keywords: Obstructive sleep apnea, weight loss, otorhinolaryngologic surgical procedures, treatment outcome

Introduction

Obstructive sleep apnea (OSA) is a common sleep-related respiratory disorder, mainly manifesting as narrowing or collapse of the airway during sleep, leading to brief pauses in breathing during sleep [1]. The disease can cause intermittent hypoxia in the body, which further leads to a series of adverse events such as hypoxemia, hypercapnia, sleep fragmentation, repeated nighttime awakening, increased respiratory effort, and increased sympathetic nerve activity [2]. Moreover, OSA correlates closely with a variety of long-term complications, which not only significantly heighten the risks of cardiovascular and cerebrovascular diseases and metabolic disorders but are also related to depression, decreased work efficiency, and increased motor vehicle accidents [3]. OSA seriously affects the quality of life of patients, and obesity is an important pathogenic factor of OSA [4, 5]. The incidence of obesity is increasing year by year worldwide [6], and more and more patients suffer from it. Surgical treatment, as one of the important interventions of OSA, is difficult to achieve satisfactory results for some

https://doi.org/10.62347/S0XN2573

patients, and weight loss treatment has been paid attention by more and more scholars [7-10]. A systematic review and meta-analysis pointed out that weight loss therapy is highly effective in reducing body mass index (BMI), apnea-hypopnea index (AHI), and respiratory disturbance index (RDI) in OSA patients, thus effectively reducing disease severity [11].

In this study, short-term follow-up observation and data analysis were performed on patients with postoperative weight loss of OSA. The innovation of this study lies in a systematic evaluation of the role played by weight loss in 200 OSA patients across various indicators such as therapeutic efficacy, polysomnography (PSG), Calgary Sleep Apnea Quality of Life Index (SAQLI), Epworth Sleepiness Scale (ESS), and Snoring Score (SS), confirming the clinical effectiveness of weight loss in OSA and providing a better choice and reference for OSA management. Additionally, the predictors of efficacy are determined by Logistic regression analysis, with a nomogram constructed and validated for curative effect evaluation, which provides an effective treatment risk stratification tool for OSA patients and helps inform clinical decision-making.

Data and methods

Patient selection

A retrospective study was conducted on 200 patients with OSA who underwent surgery in Xiaogan Hospital Affiliated to Wuhan University of Science and Technology from October 2021 to October 2024. All of the patients met the following inclusion criteria: patients who received PSG in our hospital were diagnosed as OSA according to the Chinese 2009 guidelines for the diagnosis and surgical treatment of OSA; all the patients were overweight, namely, BMI≥24 kg/m^2 (Asian standard); no obvious maxillofacial deformity; rejection or intolerance of continuous positive airway pressure (CPAP), and no recent serious medical disease; with complete medical records and follow-up data. Exclusion criteria included: the existence of significant maxillofacial skeletal deformity; previous history of upper airway surgery; additional sleep breathing disorders or severe insomnia; unstable cardiovascular events, uncontrolled severe hypertension or serious lung diseases within 3 months before enrollment; existing serious mental and neurological diseases, cognitive disorders, or substance abuse; hypercapnia (arterial partial pressure of carbon dioxide [$PaCO_2$] ≥45 mmHg); pregnancy or lactation; non-obese type 1 diabetes; inability to tolerate post-operative diet and living habits; surgical contraindications. All clinical data were retrieved through the hospital's electronic medical record system. This study was approved by the Ethics Committee of Xiaogan Hospital, which is affiliated with Wuhan University of Science and Technology. **Figure 1** shows the flowchart of the patient selection process.

All 200 patients underwent modified uvulopalatopharyngoplasty (UPPP) and lost weight in various ways after surgery. 72 patients (60 males and 12 females), with the mean age of 40.39±12.16 years and the mean BMI of 29.39±1.81 kg/m^2, whose BMI decreased by more than or equal to 4 kg/m^2 three months after surgery were included in the loss weight group (LG). 128 patients (104 males and 24 females), with the average age of 40.48±11.69 years and the average BMI of 28.77±2.85 kg/m^2 whose BMI decreased less than 4 kg/m^2 three months after surgery were included in the constant weight group (CG).

Methodology

Preoperative evaluation

(1) Medical history was inquired in detail and physical examination was conducted comprehensively to regulate and control the internal medicine diseases. (2) All patients were recorded with BMI, neck circumference (NC), waist circumference (WC), and hip circumference (HC), complete PSG monitoring and evaluation of SAQLI [12], ESS [13] and SS [14] before surgery.

Intervention measures

Surgical intervention: All patients underwent modified UPPP: The operation field was exposed through the mouth speculum. The plasma knife cut downward from about 1 cm above the free edge of the soft palate, a part of palatoglossal arch and palatopharyngeal arch were removed, and then bilateral tonsils were removed. The connective tissue and adipose tissue in the palatine sail space were removed. Cut the palatopharyngeal arch vertically upward from both

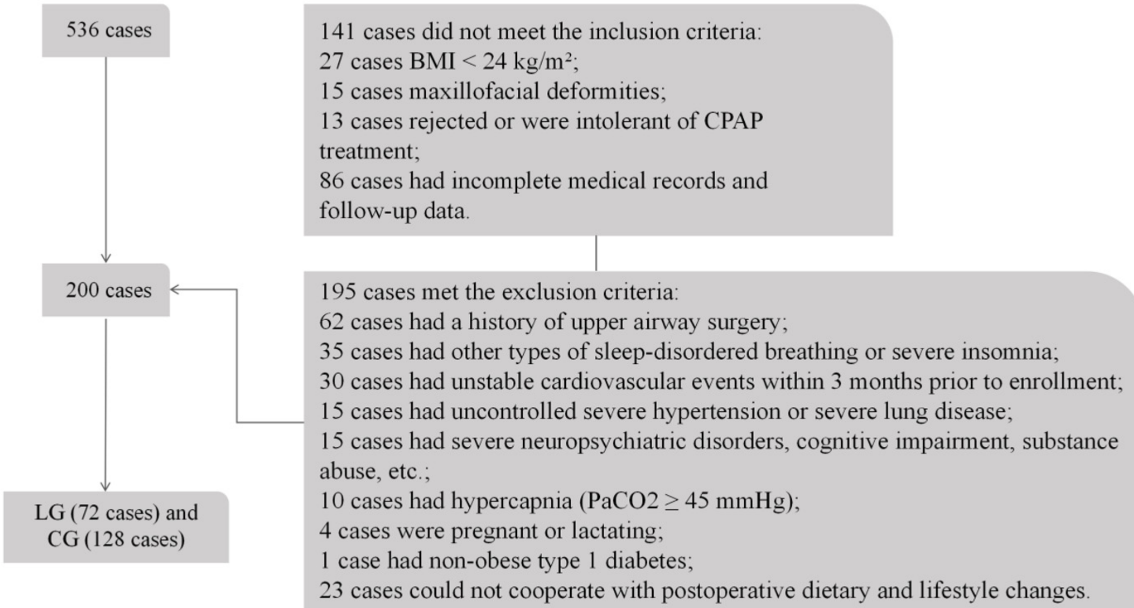

Figure 1. Patient selection flowchart. BMI: body mass index; CPAP: continuous positive airway pressure; $PaCO_2$: arterial partial pressure of carbon dioxide; LG: Loss weight group; CG: Constant weight group.

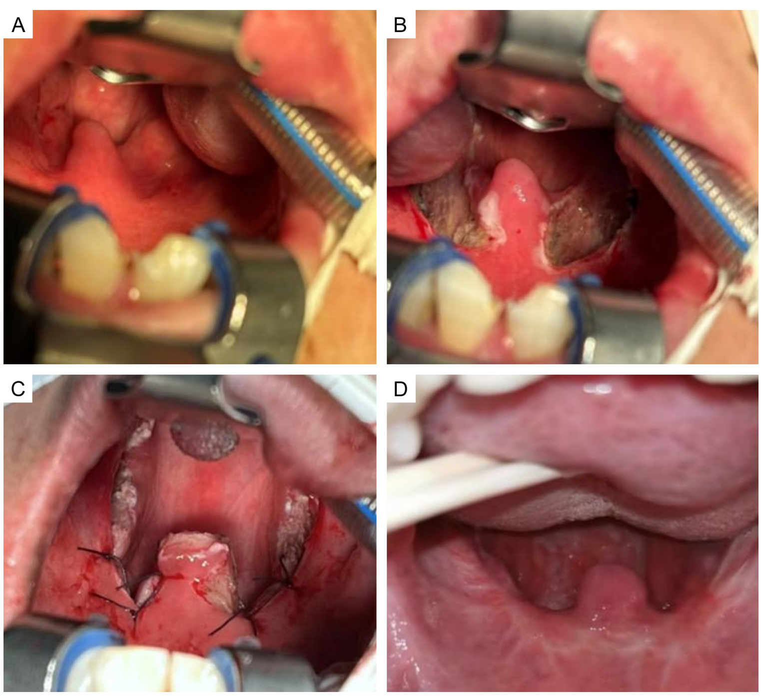

Figure 2. Modified uvulopalatopharyngoplasty (UPPP) procedure. A. Pre-surgery, the surgical site is exposed with the assistance of an oral speculum. B. Intraoperatively, an incision is made downward with a plasma scalpel, beginning roughly 1 cm above the free margin of the soft palate. A portion of the palatoglossal arch and palatopharyngeal arch is excised, followed by the removal of the tonsils on both sides. C. Post-surgery, the superior poles of the palatopharyngeal arch are sutured to the palatoglossal arch with absorbable stitches. The superior mucosal flap of the palatopharyngeal arch is then repositioned laterally and sutured to the palatoglossal arch. A partial uvulectomy is performed. D. Follow-up at 3 months shows satisfactory healing of the palatoglossal arch.

sides of the uvula to the upper pole of the newly formed palatoglossal arch. Suture the upper pole of palatopharyngeal arch and palatoglossal arch with absorbable thread, and the mucosal flap at the upper end of the palatopharyngeal arch was pulled and sutured outward to the palatoglossal arch and a part of the uvula was removed (**Figure 2**).

Lifestyle intervention: Follow up regularly after operation, and carry out healthy lifestyle intervention through centralized explanation or individual guidance. (1) Cognitive intervention. Many patients lack a correct understanding of OSA diseases and surgery. They need to carry out extensive popular science publicity and personalized guidance to explain the causes, clinical manifestations, complications, treatment methods and effects of OSA to patients and their families. In particular, they should promote that OSA is closely related to obesity, smoking, drinking and other bad habits, guide patients to establish an objective understanding, and remove psychological barriers and burdens, and emphasize that OSA treatment is a long-term comprehensive treatment process. The operation only removes the local factor of the disease. To consolidate the effect of the operation, we need to change bad behaviors and living habits, help patients to establish enough confidence and better cooperate with lifestyle intervention. (2) Dietary guidance. Strengthen communication with patients, understand their daily dietary habits, and then provide them with personalized dietary intervention, control energy intake, weight loss through scientific diet, prevent malnutrition caused by blind weight loss, and avoid use weight loss drugs. Our patient's daily diet was based on the principle of low fat, low cholesterol and rich in vitamins. Coarse flour and rice were reasonably combined, and fresh fruits and vegetables were appropriately eaten to ensure smooth stool. Guide and supervise patients to regularly measure body weight, make records, and timely improvement. (3) Quit smoking and drinking. Controlling tobacco and wine could improve the sensitivity of the body to hypoxic stimulation. Patients and their families were repeatedly introduced to the effects of alcohol and tobacco on their health, and their families and social forces were mobilized to help them quit smoking and drinking, and patients were helped to select the appropriate smoking and drinking cessation methods. (4) Exercise guidance. Discuss with patients and make appropriate exercise plan, select appropriate exercise methods according to their age and physical condition, such as walking, jogging, swimming, riding a bike, and insist on appropriate aerobic exercise every day to encourage patients to persevere exercise intensity increases or decreases dynamically with the patient's own situation, reasonable rest, and ensure adequate sleep time.

Follow-up

All patients were followed up (via telephone interview, review, case information query, etc.) for three months, during which the patients were urged and encouraged to adhere to the above lifestyle intervention. During the follow-up period, a series of clinical data of the patients three months after the operation was collected. For details, please refer to subsection 1.3 presented below.

Data extraction

In this study, a standardized data extraction process was adopted to ensure the accuracy and integrity of information. All data were extracted from the hospital electronic medical record system, PSG monitoring reports, and standardized scales filled out by patients. Data extraction was carried out independently by two trained researchers. The main data extracted and verified are as follows: (1) Efficacy. Therapeutic effect evaluation was conducted after three months of intervention with reference to specific standards. A post-treatment reduction in the AHI to below 5 events/hour was labeled as "cure"; an AHI decrease of 50% or a drop to the 5-12 events/hour range was termed "significant effect"; a noticeable AHI decline that was less than 50% was identified as "effective"; and instances failing to meet the above conditions were categorized as "ineffective". Moreover, the overall treatment effective rate was determined by dividing the sum of cases classified as "cured", "significant effect" and "effective" by the total number of cases, then converting the result to a percentage. (2) Improvement of subjective symptoms. In this study, the improvement of subjective symptoms such as snoring, awakening from suffocation (AS), daytime sleepiness (DS), memory loss, general discomfort (GD), chest tightness (CT), and palpitation was assessed three months post-intervention. (3) Lifestyle changes. The main assessment was on the lifestyle modifications made by the two groups of patients after three months of intervention, including diet control, stopping smoking, banning drinking, and continuing to exercise. (4) Intraindividual changes. Pre- v.s. post-interventional (3 months) changes in NC, WC, HC, and BMI of both groups were counted and compared. (5) PSG-related indicators. PSG-related parameters, including AHI, lowest arterial oxygen saturation (LSaO2), and the percentage of total recording time with arterial oxygen saturation (SaO2) below 90% (TS90%), were comparatively evaluated before and after intervention for 3 months. (6) Subjective scale scores. Both groups of patients were assessed for ESS, SS, daily life (DL), social interaction (SI), emotion (E), and symptom (S) scores before and 3

Table 1. Comparison of basic information between loss weight group (LG) and constant weight group (CG) ($\bar{x}$±sd)

Index	LG (72 cases)	CG (128 cases)	t/χ^2/Fisher value	*P* value
Gender (male/female)	60/12	104/24	0.136	0.713
Age (years)	40.39±12.16	40.48±11.69	0.052	0.959
BMI (kg/m^2)	29.39±1.81	28.77±2.85	1.666	0.097
OSA severity (mild + moderate/severe)	4/68	15/113		0.210
Comorbid hypertension (no/yes)	43/29	83/45	0.519	0.472
Comorbid type 2 diabetes (no/yes)	55/17	102/26	0.297	0.586
Smoking (no/yes)	48/24	92/36	0.595	0.440
Drinking (no/yes)	54/18	93/35	0.130	0.719

Notes: Obstructive sleep apnea (OSA) is graded in severity based on the Apnea-Hypopnea Index (AHI). The condition is classified as mild for an AHI of 5-14, moderate for 15-29, and severe for scores reaching 30 or above. BMI: body mass index.

Table 2. Comparative analysis of post-treatment efficacy (LG vs. CG)

Factor	LG (72 cases)		CG (128 cases)		*P* value
	Cases	Rate	Cases	Rate	
Cured	36	50.00	30	23.44	
Markedly effective	15	20.83	36	28.13	
Effective	15	20.83	21	16.41	
Ineffective	6	8.33	41	32.03	
Total efficacy	66	91.67	87	67.97	<0.001

Notes: LG: Loss weight group; CG: Constant weight group. Fisher's exact test was employed for enumeration data where the frequency count was less than 5.

months following the intervention. Among them, ESS is used to assess the patient's tendency to doze off during daily activities, SS to evaluate the severity of snoring, and SAQLI to quantify the quality of life.

Outcome measures

As far as the outcome measures are concerned, efficacy, lifestyle changes, intraindividual changes, PSG-related indicators, and subjective scale scores were primary, while the improvement of subjective symptoms was secondary.

Statistical analysis

SPSS 26.0 statistical software was used for statistical analysis. The enumeration data were subjected to χ^2 test; for those with a frequency count lower than 5, Fisher's exact test was adopted. Quantitative data conforming to the normal distribution were expressed as mean standard deviation ($\bar{x}$±sd). The data of two independent samples were t-tested for inter-group comparison, and the parameters before and after treatment were compared by paired t-test, where P<0.05 indicated statistically significant difference. The correlation between the basic indicators, subjective scale scores, and the severity of OSA was evaluated using Pearson/Spearman correlation coefficients. Determinants of patient outcomes were examined through univariate analysis and multivariate logistic regression modeling. Subsequently, a predictive nomogram was constructed. The model's performance underwent internal validation with 1000 bootstrap replicates and was assessed via calibration curves.

Results

Inter-group comparison of general information

The two groups exhibited no significant difference in gender (χ^2=0.039), age, BMI, OSA severity, comorbid hypertension/type 2 diabetes, smoking, and drinking (all P>0.05) (**Table 1**).

Enhancement of clinical efficacy post-intervention in the two groups

The overall treatment efficacy was significantly superior in the LG versus the CG after the procedure and lifestyle modifications (P<0.05) (**Table 2**).

Improvement of subjective symptoms after intervention in the two groups

After operation and lifestyle intervention, the improvement rate of subjective symptoms

Table 3. Comparison of the improvement rate of subjective symptoms after the intervention of LG and CG

Subjective symptoms	LG (72 cases)		CG (128 cases)		χ^2 value	*P* value
	Cases	Rate	Cases	Rate		
Snoring	72	1.000	95	0.742	22.231	<0.001
AS	57	0.792	66	0.516	14.830	<0.001
DS	48	0.667	48	0.375	15.705	<0.001
Memory Loss	69	0.958	92	0.719	-	<0.001[b]
GD	54	0.750	57	0.445	17.321	0.015
CT	60	0.833	101	0.789	0.575	0.448
Palpitation	51	0.708	57	0.445	12.833	<0.001

Notes: The notation 'b' indicates that the data were analyzed using Fisher's exact test. LG: Loss weight group; CG: Constant weight group; AS: awakening from suffocation; DS: daytime sleepiness; GD: general discomfort; CT: chest tightness.

Table 4. Comparison of lifestyle changes between loss weight group (LG) and constant weight group (CG)

Lifestyle	LG (72 cases)		CG (128 cases)		χ^2 value	*P* value
	Cases	Rate	Cases	Rate		
Diet control	57	0.792	60	0.469	19.792	<0.001
Stop smoking ban drinking	39	0.542	35	0.273	14.223	<0.001
Keep exercising	45	0.625	48	0.375	11.577	<0.001
	66	0.917	89	0.695	12.948	<0.001

between LG and CG was statistically significant (P<0.05), including snoring, AS, DS, memory loss, GD and palpitation, except CT (**Table 3**).

Comparison of lifestyle changes between the two groups

The differences in diet control, stop smoking, ban drinking, and keep exercising between the two groups after intervention are statistically significant (P<0.05) (**Table 4**).

Intraindividual changes before and after intervention in the two groups

There was no significant difference in NC, WC, and HC between the two groups before intervention (all P>0.05, as shown in **Table 5** $t_1(P)$ value). The NC and WC of the LG were significantly different before and after intervention, while the HC was not significantly different (as shown in **Table 5** $t_2(P)$ value). However, there was no significant difference in neck, waist and HC in the CG before and after intervention (all P>0.05, as shown in **Table 5** $t_3(P)$ value).

Comparison of PSG related indexes and subjective scale scores before and after intervention

There was no significant difference in AHI, LSaO2, TS90%, SAQLI total score and four dimension scores (DL, SI, E, and S), as well as ESS and SS scores, between the LG and the CG before intervention (all P>0.05, as shown in **Tables 6** and **7** $t_1(P)$ value). Three months after intervention, the total scores of LG in AHI, LSaO2, TS90%, and SAQLI as well as the scores in four dimensions, ESS and SS were all significantly improved as compared with those before intervention (all P<0.01, as shown in **Tables 6** and **7** $t_2(P)$ values). Compared with the CG, the differences were also statistically significant (P<0.05, as shown in **Tables 6** and **7** $t_4(P)$ value).

Correlation analysis

Correlation analysis showed that BMI, LSaO2, TS90%, NC and WC were all significantly correlated with the severity of OSA except HC (**Table 8** and **Figure 3**). In the subjective scales, except social interaction dimension, there was a significant correlation with the severity of OSA (**Table 9** and **Figure 4**).

Table 5. Intraindividual changes in loss weight group (LG) and cconstant weight group (CG) before and after intervention ($\overline{x}\pm sd$)

Observation index	LG (n=72)	CG (n=128)	t value	*P* value
NC (cm)				
Pre-intervention	41.10±2.09	41.00±2.29	0.305	0.761
Post-intervention	39.13±1.60	41.15±2.28	6.650	<0.001
t value	6.351	0.525		
P value	<0.001	0.600		
WC (cm)				
Pre-intervention	110.91±8.02	113.16±10.03	1.632	0.104
Post-intervention	103.03±7.49	112.92±10.52	7.034	<0.001
t value	6.093	0.852		
P value	<0.001	0.187		
HC (cm)				
Pre-intervention	116.16±8.72	115.31±9.74	0.615	0.540
Post-intervention	112.32±8.89	115.85±9.65	2.553	0.011
t value	2.617	0.446		
P value	0.010	0.656		
BMI (kg/m^2)				
Pre-intervention	29.39±1.81	28.77±2.85	1.666	0.097
Post-intervention	24.36±1.54	28.12±2.50	11.580	<0.001
t value	17.960	1.940		
P value	<0.001	0.054		

Notes: NC: neck circumference; WC: waist circumference; HC: hip circumference; BMI: body mass index.

Table 6. Comparison of polysomnography (PSG)-related indexes between loss weight group (LG) and constant weight group (CG) before and after intervention ($\overline{x}\pm sd$)

Observation index	LG (n=72)	CG (n=128)	t value	*P* value
AHI (events/hour)				
Pre-intervention	59.53±19.02	58.58±23.90	0.235	0.815
Post-intervention	36.57±17.20	50.85±18.50	5.372	<0.001
t value	7.597	2.894		
P value	<0.001	0.004		
LSaO2				
Pre-intervention	0.69±0.09	0.71±0.09	1.508	0.133
Post-intervention	0.84±0.11	0.77±0.09	4.866	<0.001
t value	8.955	5.333		
P value	<0.001	<0.001		
TS90% (%)				
Pre-intervention	28.48±16.74	29.76±15.67	0.541	0.589
Post-intervention	18.07±11.26	24.00±13.98	3.080	0.002
t value	4.379	3.103		
P value	<0.001	0.002		

Notes: AHI: apnea-hypopnea index; LSaO2: lowest arterial oxygen saturation; TS90%: the percentage of total recording time with arterial oxygen saturation (SaO2) below 90%.

Univariate analysis

All the potential factors of ineffective treatment were analyzed by univariate analysis. The patient's therapeutic effect was significantly associated with BMI, NC, diet control, and keeping exercise (P<0.05), but not with gender, age, OSA severity, comorbid hypertension/type 2 diabetes, smoking, drinking, WC, HC, AHI, LSaO2, TS90%, ESS, SS, SAQLI total score, stop smoking, or ban drinking (P>0.05) (**Table 10**).

Logistic regression analysis

Taking the treatment effectiveness (effective =0, ineffective =1) as the dependent variable, and taking BMI, NC before intervention, whether to control diet, and keep exercising as the independent variables, Logistic regression analysis of risk factors was carried out. The results show that BMI, NC, diet control and persistent exercise are the influencing factors for the treatment of OSA (**Table 11**).

Bootstrapping validation (n=1000) yielded a C-index of 0.805 (95% CI: 0.721-0.884), suggesting the model's strong discriminatory ability. Assessment of calibration showed satisfactory agreement in the low-to intermediate-risk ranges but potential inaccuracies in the high-risk range (**Figure 5**).

Discussion

The pathogenesis of OSA is complex and involves many clinical disciplines. With the improvement of living standards, obesity has become a very prominent global topic [15, 16], and the close relationship between OSA and obesity has been confirmed by many scholars [4, 5, 17].

Table 7. Comparison of subjective scales between loss weight group (LG) and constant weight group (CG) before and after intervention ($\bar{x}$±sd)

Observation index	LG (n=72)	CG (n=128)	t value	*P* value
ESS (score)				
Pre-intervention	13.36±4.21	14.11±5.12	1.058	0.292
Post-intervention	8.96±4.68	12.13±4.27	4.867	<0.001
t value	5.931	3.360		
P value	<0.001	<0.001		
SS (score)				
Pre-intervention	7.01±0.85	6.82±1.08	1.285	0.200
Post-intervention	4.97±1.62	5.91±1.54	4.066	<0.001
t value	9.462	5.474		
P value	<0.001	<0.001		
SAQLI total score				
Pre-intervention	4.51±0.83	4.69±0.91	1.385	0.168
Post-intervention	5.44±0.69	5.03±0.71	3.960	<0.001
t value	7.311	3.333		
P value	<0.001	0.001		
DL score				
Pre-intervention	4.83±0.95	4.69±0.99	0.974	0.331
Post-intervention	5.39±0.83	5.02±0.87	2.935	0.004
t value	3.767	2.833		
P value	<0.001	0.005		
SI score				
Pre-intervention	4.58±0.91	4.51±0.99	0.494	0.622
Post-intervention	5.42±0.77	4.87±0.90	4.363	<0.001
t value	5.979	3.044		
P value	<0.001	0.003		
E score				
Pre-intervention	4.61±0.85	4.59±0.91	0.153	0.879
Post-intervention	5.58±0.93	5.05±0.88	4.005	<0.001
t value	6.533	4.111		
P value	<0.001	<0.001		
S score				
Pre-intervention	4.42±0.89	4.44±0.79	0.164	0.870
Post-intervention	5.43±0.91	4.91±0.91	3.879	<0.001
t value	6.733	4.413		
P value	<0.001	<0.001		

Notes: ESS: Epworth Somnolence Scale; SS: snoring score; SAQLI: Sleep Apnea Quality of Life Index; DL: daily life; SI: social interaction; E: emotion; S: symptom.

Weight loss has become the main treatment of OSA [7-10]. Even in the 2013 edition of the US *Normative Diagnosis and Treatment Guidelines for OSA*, it was clearly pointed out that patients with OSA who were accompanied with obesity should undergo weight loss treatment [18]. As otorhinolaryngology head and neck surgeons, we know that most patients with OSA will lose weight due to eating pain after surgery. If we can maintain weight loss after surgery and further lose weight through various methods, will it increase the success rate of surgery or enhance the curative effect of surgery? In this study, besides comparing the PSG-related objective indicators before and after OSA intervention, SAQLI, ESS, SS scales and changes of conscious symptoms were also added to evaluate the subjective symptoms and changes in quality of life of patients. As shown in **Tables 8** and **9**, most indicators have a good correlation with the severity of OSA, and they are very suitable reference indicators. Our study showed that after three months of surgery and various weight loss interventions, AHI, LSaO2, TS90%, and the total scores of SAQLI as well as its four dimension scores, ESS score and SS score in the LG were all significantly improved as compared with those before surgery. In the study by Cho et al. [19], the application of smartphone-based lifestyle modification for obese patients with OSA was found to be effective in reducing their body weight. Moreover, the AHI of the patients who successfully achieved weight loss showed a significant decrease after 4 weeks of intervention, a finding similar to the results of this study. According to Kline et al. [20], exercise training for adult OSA patients who are sedentary and overweight/obese significantly reduces AHI and oxygen saturation index while helping improve subjective sleep quality, which complements the results of this study. Yılmaz et al. [21] noted that laparoscopic sleeve gastrectomy can not only effectively reduce BMI and AHI, but also significantly improve PSG-associated parameters such as sleep quality and desaturation index, which are complementary to our findings. The differences were also statistically significant compared with the CG. The subjective symptoms of LG were also significantly improved compared with that of CG, indicating that weight loss is an important supplement for

Table 8. Correlation analysis between basic indicators and severity of OSA

	BMI	LSaO2	TS90%	NC	WC	HC
R value	0.484	0.479	0.631	0.555	0.445	0.033
P value	<0.001	<0.001	<0.001	<0.001	<0.001	0.640

Notes: BMI: body mass index; LSaO2: lowest arterial oxygen saturation; TS90%: the percentage of total recording time with arterial oxygen saturation (SaO2) below 90%; NC: neck circumference; WC: waist circumference; HC: hip circumference.

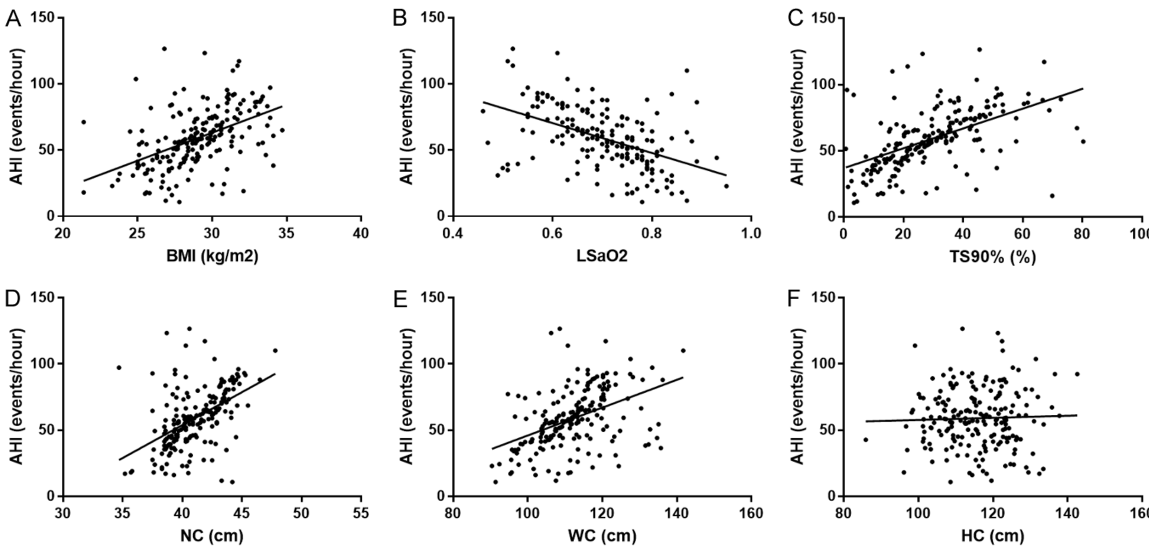

Figure 3. Correlation analysis between basic indicators and severity of OSA. A. BMI-AHI correlation. B. LSaO2-AHI correlation. C. TS90%-AHI correlation. D. NC-AHI correlation. E. WC-AHI correlation. F. HC-AHI correlation. BMI: body mass index; LSaO2: lowest arterial oxygen saturation; TS90%: the percentage of total recording time with arterial oxygen saturation (SaO2) below 90%; NC: neck circumference; WC: waist circumference; HC: hip circumference.

Table 9. Correlation analysis between scores of subjective scale and severity of OSA

	ESS	SS	SAQLI total score	DL score	SI score	E score	S score
R value	0.538	0.168	-0.482	-0.491	-0.124	-0.295	-0.278
P value	<0.001	0.018	<0.001	<0.001	0.080	<0.001	<0.001

Notes: ESS: Epworth Somnolence Scale; SS: snoring score; SAQLI: Sleep Apnea Quality of Life Index; DL: daily life; SI: social interaction; E: emotion; S: symptom.

surgical treatment of OSA patients. In the study by Bailly et al. [22], the weight loss rehabilitation program applied to overweight/obese patients is shown to be effective in reducing body weight and significantly improving OSA as well as subjective DS, supporting our observations.

At present, the mechanism of weight loss in the treatment of obesity accompanied with OSA is not completely clear. Studies have shown that NC and WC mainly reflect the distribution of fat, which is accumulated in the neck, chest and abdomen, limiting the mechanical movement of chest and abdomen, and increasing the consumption of respiratory-related muscle movement [23, 24]. At the same time, the fat accumulated in the root of the tongue and the pharyngeal cavity blocks the upper airway and limits the contraction and expansion capacity of the respiratory-related muscles in the upper airway [25, 26]. Weight loss will reduce the accumulation of adipose tissue around the upper airway of patients, thereby alleviating upper airway stenosis [5, 27]; reducing chest and abdomen fat will improve the compliance of chest and abdominal wall and increase lung capacity [28]. In **Table 5** of this study, the NC and WC are obviously reduced, which shows that the NC and WC are obviously related to

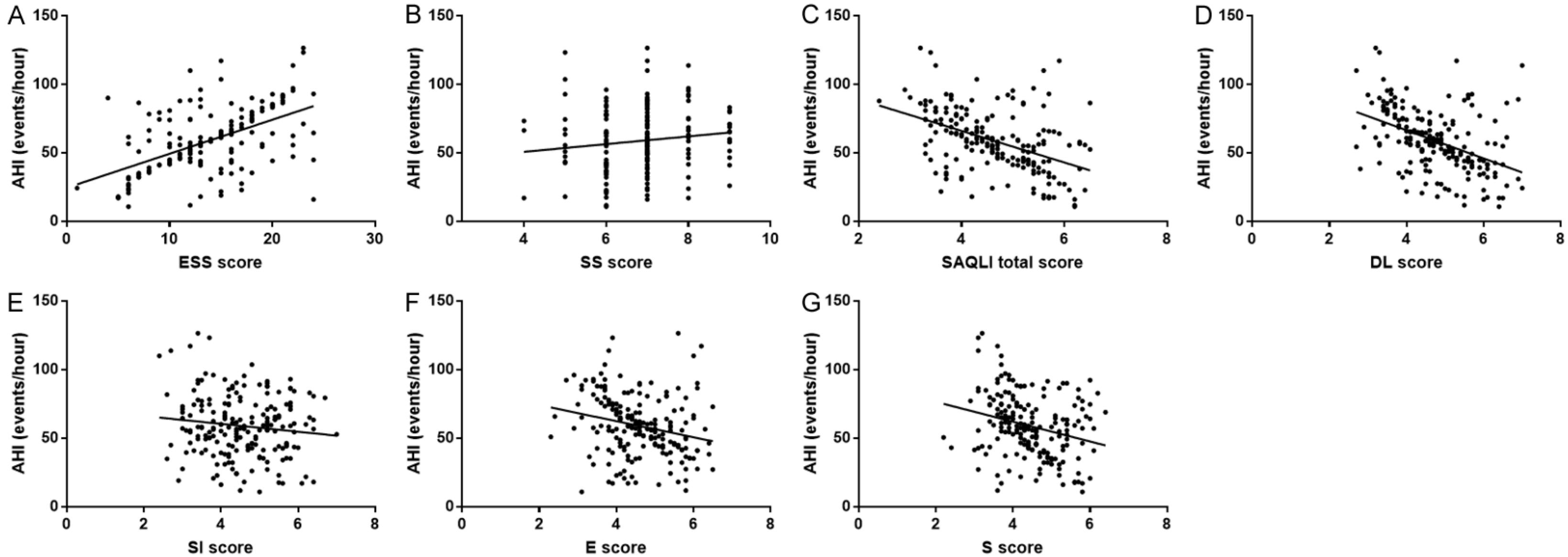

Figure 4. Correlation analysis between scores of subjective scale and severity of OSA. A. ESS score-AHI correlation. B. SS score-AHI correlation. C. SAQLI total score-AHI correlation. D. DL score-AHI correlation. E. SI score-AHI correlation. F. E score-AHI correlation. G. S score-AHI correlation. ESS: Epworth Somnolence Scale; SS: snoring score; SAQLI: Sleep Apnea Quality of Life Index; DL: daily life; SI: social interaction; E: emotion; S: symptom.

Table 10. Univariate analysis of risk factors for OSA treatment

Observation index	Ineffective group (n=47)	Effective group (n=153)	χ^2/t value	*P* value
Gender			0.402	0.526
Male (n=164)	40 (85.11)	124 (81.05)		
Female (n=36)	7 (14.89)	29 (18.95)		
Age (years)	39.13±11.16	40.85±12.04	0.871	0.385
BMI (kg/m^2)	30.52±2.91	28.53±2.22	4.976	<0.001
OSA severity			2.079	0.149
Mild + moderate (n=19)	7 (14.89)	12 (7.84)		
severe (n=181)	40 (85.11)	141 (92.16)		
Comorbid hypertension (n=74)	22 (46.81)	52 (33.99)	2.536	0.111
Comorbid type 2 diabetes (n=43)	13 (27.66)	30 (19.61)	1.381	0.240
Smoking (n=60)	15 (31.91)	45 (29.41)	0.107	0.743
Drinking (n=53)	13 (27.66)	40 (26.14)	0.042	0.837
NC (cm)	42.06±2.50	40.72±2.03	3.740	<0.001
WC (cm)	117.78±11.73	110.69±7.88	0.438	0.662
HC (cm)	115.92±10.07	115.52±9.18	0.255	0.799
AHI (events/hour)	58.08±22.22	61.65±22.25	0.962	0.337
LSaO2	0.71±0.09	0.69±0.09	1.332	0.184
TS90% (%)	28.87±16.46	30.69±14.66	0.723	0.471
ESS (score)	13.50±4.67	14.94±5.15	1.712	0.088
SS (score)	6.88±1.03	6.91±0.93	0.189	0.851
SAQLI total score	4.64±0.88	4.55±0.90	0.603	0.547
diet control (n=117)	19 (40.43)	98 (64.05)	8.267	0.004
stop smoking (n=74)	17 (36.17)	57 (37.25)	0.018	0.893
ban drinking (n=93)	20 (42.55)	73 (47.71)	0.385	0.535
keep exercising (n=155)	26 (55.32)	129 (84.31)	17.334	<0.001

Notes: OSA: obstructive sleep apnea; BMI: body mass index; LSaO2: lowest arterial oxygen saturation; TS90%: the percentage of total recording time with arterial oxygen saturation (SaO2) below 90%; NC: neck circumference; WC: waist circumference; HC: hip circumference; AHI: apnea-hypopnea index; ESS: Epworth Somnolence Scale; SS: snoring score; SAQLI: Sleep Apnea Quality of Life Index.

Table 11. Logistic regression analysis of risk factors for OSA treatment

Index	B	SE	WALD	P	OR	95% CI
BMI (continuous variable)	0.288	0.083	12.067	0.001	1.334	1.134-1.569
NC (continuous variable)	0.231	0.094	6.048	0.014	1.260	1.048-1.515
diet control (no =0, yes =1)	-1.118	0.396	7.994	0.005	0.327	0.151-0.710
keep exercising (no =0, yes =1)	-1.161	0.417	7.761	0.005	0.313	0.138-0.709

Notes: OSA: obstructive sleep apnea; BMI: body mass index; NC: neck circumference.

weight loss. In **Table 11**, Logistic regression analysis shows that BMI, NC, diet control and persistent exercise, which are obviously related to weight, are just the important influencing factors in the treatment of OSA, which shows the importance of weight loss in the treatment of OSA. Timmerman et al. [29] identified NC as an independent predictor of OSA remission in severely obese patients undergoing sleeve gastrectomy, which echoes the results observed in our investigation. In the analysis of Huang et al. [30], the preoperative age, AHI, fasting C-peptide level, and hippuric acid level of OSA patients could serve as combined predictive indicators for the efficacy of Roux-en-Y gastric bypass surgery, with extremely high diagnostic performance (area under the curve 0.947), which are complementary to our findings. Puech et al. [31] further demonstrated the role of high preoperative average oxygen saturation as an independent predictor of OSA regression in patients undergoing bariatric surgery, com-

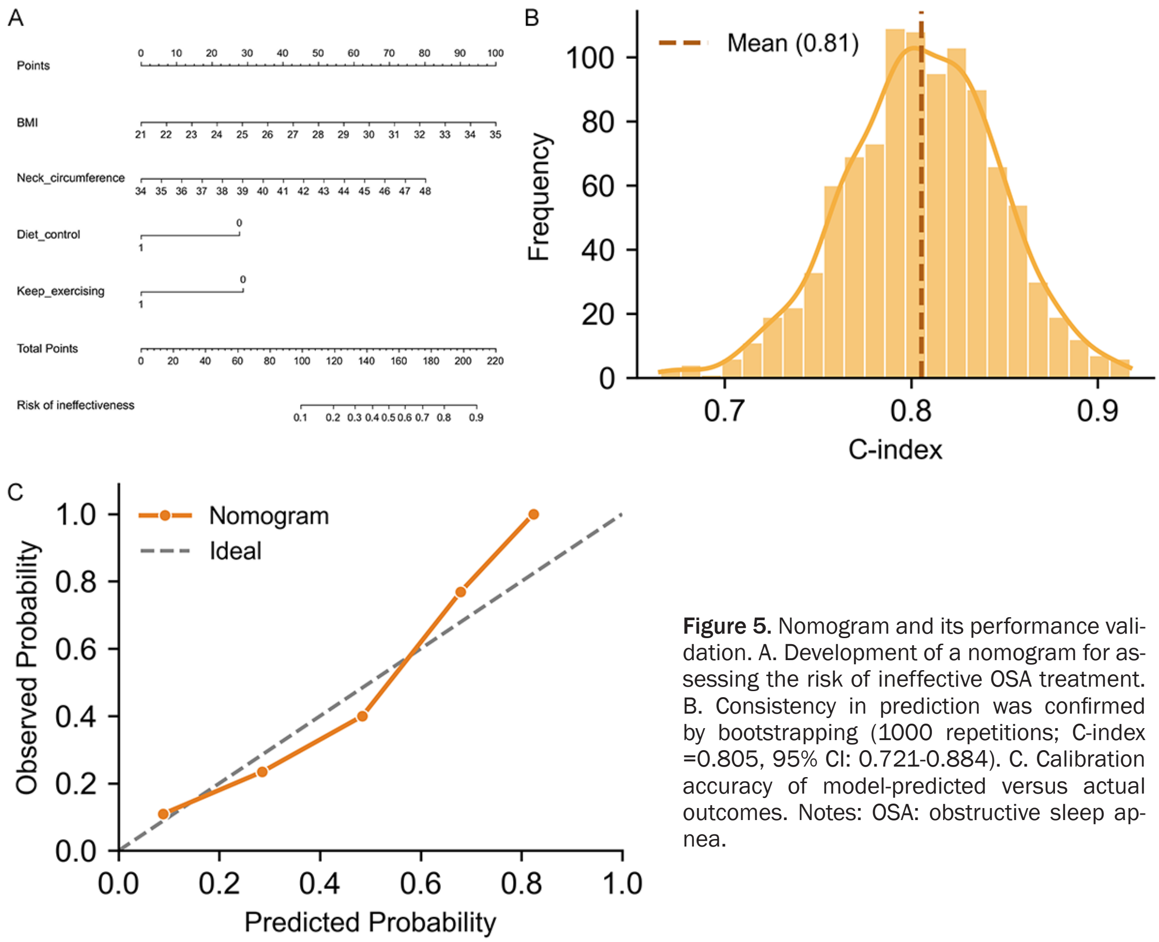

Figure 5. Nomogram and its performance validation. A. Development of a nomogram for assessing the risk of ineffective OSA treatment. B. Consistency in prediction was confirmed by bootstrapping (1000 repetitions; C-index =0.805, 95% CI: 0.721-0.884). C. Calibration accuracy of model-predicted versus actual outcomes. Notes: OSA: obstructive sleep apnea.

plementing the results of this study. Furthermore, the resulting nomogram demonstrated strong discriminatory ability, with accurate calibration across the low- and intermediate-risk ranges. Weight loss also helps to reduce hypertension, diabetes and other independent risk factors related to OSA and indirectly improves the symptoms of OSA [32-34]. Some studies also believe that OSA is a systemic disease including psychological disorders [35]. Patients with OSA and obesity often suffer from weight loss, while successful weight loss will enhance patients' confidence in victory over the disease, reduce patients' guilt and anxiety that their snoring affects others, promote patients' normal contact and communication with others, and improve patients' psychological state. In this study, the lifestyle changes of the LG, such as controlling diet, quitting smoking and drinking, and insisting on exercise, are obviously better than those of the CG. It shows that the psychological status and physical condition of patients have been improved after effective healthy lifestyle intervention, and thus improving their quality of life subjectively. In the research of Raj et al. [36], lifestyle intervention based on customized and appropriate diet plans was used for patients with OSA and proved to be an effective adjunctive therapy. They effectively reduced PSG-related parameters such as AHI in patients, similar to the results of this study. Carneiro-Barrera et al. [4] pointed out that interdisciplinary weight loss and lifestyle interventions not only alleviated the condition of patients with moderate and severe OSA but also effectively enhanced their health-related quality of life, consistent with the findings of the present study.

There are some limitations in this study that need to be further improved. First, as a single-center retrospective study, there may be selection bias and information bias, warranting multi-center and larger sample size analysis in the future to improve the accuracy of the research results. Second, too short a follow-up period (3 months) makes it impossible to reveal the long-term effects and stability, as well as the possible rebound situations post-operation. Subsequent follow-up data for 3 to 5 years should be collected to verify the long-term durability of therapeutic effects and provide a basis for the long-term optimization of the treatment strategy. Finally, the research population was restricted to patients who had undergone surgery and were willing to participate in postoperative weight loss management. Future studies should include patient groups with different surgical histories or varying levels of willingness to undergo strict weight loss, in order to obtain a more universally applicable clinical decision-making basis.

In summary, effective weight control after surgery can significantly improve the short-term efficacy of patients with OSA and their quality of life.

Acknowledgements

This study was supported by the 2024 Hubei Province Xiaogan City Natural Science Program Project, Project Title: The Influence of Weight Loss on the Efficacy of OSAHS Surgery, Project Number: XGKJ2024010049.

Disclosure of conflict of interest

None.

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