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RESEARCH ARTICLE

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Understanding adherence to continuous positive airway pressure in patients with obstructive sleep apnea post-stroke: A prospective study based on the Andersen model

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Abstract

Adherence to continuous positive airway pressure (CPAP) in patients with obstructive sleep apnea (OSA) post-stroke is often problematic, despite potential benefits. This study aimed to evaluate CPAP adherence in patients with OSA post-stroke based on the Andersen behavioral model of health services utilization. A total of 227 eligible participants were recruited from a Chinese hospital. After baseline assessment, participants were followed for 6 months to determine short-term CPAP adherence. Those with good short-term adherence were followed for an additional 6 months to explore long-term adherence and influencing factors. Short-term CPAP adherence rate was 33%. Being married or living with a partner, having an associate degree or baccalaureate degree or higher, and stronger health beliefs independently predicted short-term CPAP adherence. Only 25% of participants from the adherent group showed good long-term adherence. The factor associated with long-term CPAP adherence was participants not using alcohol. Adherence to CPAP is suboptimal among patients having OSA post-stroke. Addressing unfavorable predisposing factors and modifying health beliefs are suggested.

KEYWORDS

adherence, continuous positive airway pressure, obstructive sleep apnea, predictors, stroke

Key points

- Despite potential therapeutic advantages, patients with obstructive sleep apnea post-stroke exhibit suboptimal adherence to continuous positive airway pressure.
- Marital status, educational attainment, health beliefs, and alcohol consumption are associated with adherence to continuous positive airway pressure in patients with obstructive sleep apnea post-stroke.
- Targeting unfavorable predisposing factors and modifying health beliefs may help improve adherence to continuous positive airway pressure in patients with obstructive sleep apnea post-stroke.

1 | INTRODUCTION

Obstructive sleep apnea (OSA) is a common but often-neglected complication post-stroke, with a prevalence rate of up to 70% (Johnson & Johnson, 2010). Patients who developed OSA post-stroke were more likely to show poorer neurological function, lower independence, and reduced cognitive function (Kumar et al., 2017; Zhu et al., 2022). Concomitant OSA may further increase risk of recurrence and mortality in patients with stroke (Hale et al., 2023). Appropriate interventions for managing OSA post-stroke are essential to improve patient outcomes.

Continuous positive airway pressure (CPAP) is the recommended treatment for primary OSA in the general population (Patil et al., 2019). It also has considerable benefit for OSA developed post-stroke. A clinical trial shows that 4 weeks of CPAP significantly improved attention and executive ability in patients with OSA post-stroke (Aaronson et al., 2016). Other studies support positive effects of CPAP on neurological function, motor skills, and depressive symptoms in patients with OSA post-stroke (Balcan et al., 2019; Minnerup et al., 2012; Ryan et al., 2011). Early initiation and long-term maintenance of CPAP may prevent stroke recurrence and death (Hale et al., 2023). It should be noted that the effectiveness of CPAP is dependent on patient adherence (Lin et al., 2020). However, adherence to CPAP is a considerable challenge in patients with OSA post-stroke.

2 | BACKGROUND

A systematic review found that adherence to CPAP for managing OSA post-stroke was approximately 30%–60% (Hale et al., 2023). Patient adherence to CPAP tends to decrease with treatment duration (Kendzerska et al., 2019). Compromised adherence increases the risk of stroke recurrence (Mohamed et al., 2023). Factors associated with adherence to CPAP in patients with OSA post-stroke have not been well identified. Kendzerska et al. (2019) found that factors predicting poor adherence to CPAP in patients with OSA post-stroke included older age, female gender, smoking behavior, and stroke-induced functional impairments. However, the study is a retrospective analysis of information from medical records, which lacks objective documentation of CPAP utilization. Colelli et al. (2020) showed that higher levels of disability and daytime fatigue post-stroke predicted poor adherence to CPAP at 6-month follow-up. Nevertheless, only 88 cases were included in the study, which reduced the statistical power of the analysis. Šiarnik et al. (2022) identified that patients with stroke who have higher minimum nocturnal oxygen saturation showed worse adherence to CPAP at 6-month follow-up. Similarly, the study was based on a small sample size ($n = 34$), which prevented the researcher from completing multivariate analysis. It is also worth noting that these limited studies were conducted in Western countries such as Canada and Slovakia, with no studies conducted in Asia, including China. A large international randomized controlled trial on use of CPAP for secondary prevention of recurrence in patients with OSA after cardiovascular disease showed that, in addition to severity of OSA symptoms, a history of cardiovascular disease, a fixed pressure of CPAP, and country of origin were important factors associated with patients' long-term adherence to CPAP (Van Ryswyk et al., 2019). It called for greater attention to patients from emerging economies such as China and India in view of their poor CPAP adherence and the large patient population (Van Ryswyk et al., 2019).

To gain a more comprehensive understanding of factors that influence adherence to CPAP in patients with OSA post-stroke, the current study adopted the Andersen behavioral model of health services utilization (Andersen model) as the conceptual framework (Figure 1). This model considers the association of predisposing factors, enabling factors, need factors, and personal health practices with adherence to CPAP (Andersen, 2008). It has been widely applied in studies assessing utilization of various health care services and has proven to be a valid conceptual framework (Lederle et al., 2021).

The aim of this study is to identify factors that can influence adherence to CPAP in patients with OSA post-stroke based on the Andersen model. It can provide rich empirical evidence for the development of supportive intervention programs.

3 | METHODS

3.1 | Design and sample

This prospective observational study was conducted using convenience sampling to recruit participants from the stroke unit of a hospital in Shenzhen, China between January 2019 and June 2022. Inclusion criteria were: (i) age ≥18 years; (ii) newly diagnosed with first ever stroke according to World Health Organization (WHO) criteria (WHO, 1989) in combination with brain computed tomography (CT) or magnetic resonance imaging (MRI); (iii) duration of stroke onset >1 week; (iv) meeting OSA diagnostic criteria of positive polysomnography (PSG) findings combined with apnea–hypopnea index (AHI) ≥5 events/h with symptoms or AHI ≥15 events/h without symptoms (Qaseem et al., 2014); and (v) willing to receive CPAP. Exclusion criteria were: (i) diagnosis of other serious organic diseases (e.g., malignant tumor, heart failure) or mental health issues (e.g., anxiety disorder, major depression, psychosis, cognitive impairment); (ii) pregnancy; (iii) already undergoing CPAP before study enrollment; and (iv) currently taking sedatives influencing cognitive performance. Based on the rule of 10 events per variable (Peduzzi et al., 1996), the inclusion of 220 eligible participants meets the basic sample size requirement for multivariate analysis having seven independent variables given an adherence rate of 30%. Reporting of the study followed the strengthening the reporting of observational studies in epidemiology (STROBE) guidelines (von Elm et al., 2007).

3.2 | Variables and measurements

Independent variables in this study were organized as predisposing factors, enabling factors, need factors, and personal health practices according to the Andersen model (Figure 1).

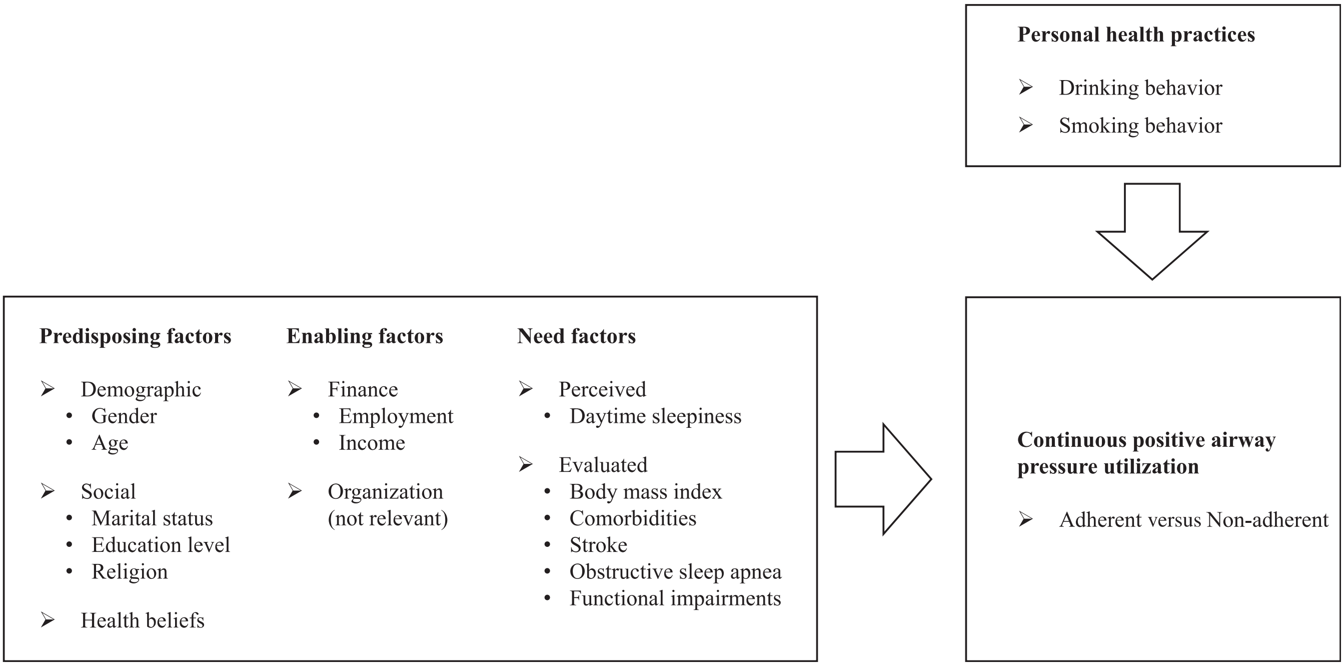

FIGURE 1 Conceptual framework of study adapted from the Anderson model to explain patient adherence to continuous positive airway pressure.

Predisposing factors included demographic characteristics (i.e., gender, age), social structure (i.e., marital status, education level, religion), and health beliefs. Health beliefs were measured using a self-administered 19-item Health Belief Scale (Appendix) adapted from Champion's Health Belief Model (Champion, 1999) and its modifications (Wu et al., 2020). These include items regarding perceived susceptibility (two items), perceived severity (three items), perceived benefits (four items), perceived barriers (six items), perceived cues to action (one item), and self-efficacy for treatment (three items). This scale is scored using a 5-point Likert scale (0 = "*strongly disagree*" to 4 = "*strongly agree*"), with higher scores indicating stronger health beliefs on use of CPAP for managing OSA post-stroke. The Health Belief Scale showed good internal consistency reliability (Cronbach's alpha = 0.82) in the current study.

Since all participants had public insurance covering regular health care provided by the study hospital while CPAP treatment was out-of-pocket, this study considered participant employment status and monthly household income as enabling factors. Health policy and health care organization were assumed to be balanced among the participants and therefore were not considered enabling factors.

Need factors included perceived health, that is, daytime sleepiness, and objectively measured health, that is, body mass index (BMI), comorbid hypertension and type 2 diabetes, neck and waist circumferences, severity of stroke and OSA, swallowing function, and dependence in activities of daily living.

The Chinese version of the Epworth Sleepiness Scale (ESS) was used to assess self-perceived daytime sleepiness in eight different contexts; each item is scored using a 4-point Likert scale (0 = "*would never nod off*" to 3 = "*high chance of nodding off*"), with a total score of 24. Higher scores indicate a greater experience of excessive sleepiness during the day. A previous study demonstrated good internal consistency reliability (Cronbach's alpha = 0.81) of the Chinese version of the ESS (Chen et al., 2002). Similarly, in the current study, the Chinese version of the ESS also exhibited excellent internal consistency reliability, with Cronbach's alpha of 0.94. A cut-off value of ≥10 was defined as excessive daytime sleepiness (Johns, 1991).

Weight and height of participants were measured to calculate BMI based on the formula of BMI = body weight (kg)/height^2 (m^2). Participant BMI was classified into four grades according to criteria proposed by the WHO for an Asian population (World Health Organization Regional Office for the Western Pacific, 2000), which includes grade 1 underweight: BMI < 18.5 kg/m^2; grade 2 normal weight: BMI 18.5–22.9 kg/m^2; grade 3 overweight: BMI 23–24.9 kg/m^2; and grade 4 obese: BMI ≥ 25 kg/m^2. Comorbid hypertension was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg according to the 2010 Chinese hypertension guidelines (Writing Group of 2010 Chinese Guidelines for the Management of Hypertension, 2011). Comorbid type 2 diabetes was defined as fasting blood glucose ≥7 mmol/L and/or plasma glucose of 2-h oral glucose tolerance test ≥11.1 mmol/L according to WHO criteria (World Health Organization International Diabetes Federation, 2006).

Neck circumference was measured at a point five millimeters above the cricothyroid cartilage, while waist circumference was measured at the midpoint between the lower edge of the rib cage and the iliac crest. These measurements were obtained using a tape measure with millimeter precision, while the participant was in either a standing or supine position.

The 11-item National Institutes of Health Stroke Scale (NIHSS) was used to identify the severity of stroke by evaluating neurological deficits induced by stroke (Lyden et al., 2001). The total score of the NIHSS ranges from 0 to 42, with higher scores indicating greater severity of stroke.

A series of PSG indices measured at diagnosis were used as proxies for the severity of OSA, and included the AHI calculated as the average frequency of hypo- and apneic episodes and hypoventilations that occur per hour of sleep, maximum apnea duration, minimum oxygen saturation, and average oxygen saturation.

The modified 30 mL water-swallowing test was used to assess swallowing function (Nishiwaki et al., 2005). Participants were instructed to drink 30 mL of water within 5 s in a usual sitting position. Those who completed the test without interruption or choking were considered as having normal swallowing function.

The 10-item modified Barthel index (MBI) was used to measure participant dependence in activities of daily living, with a total score ranging from 0 to 100. Higher scores indicate less dependence in activities of daily life. According to a previous study, the MBI has excellent internal consistency reliability (Cornbach's alpha = 0.93) in Chinese patients with stroke (Leung et al., 2007). This is consistent with the current study, which revealed a Cronbach's alpha of 0.94, indicating strong internal consistency reliability.

Personal health practices were smoking and alcohol consumption behaviors. Participants were classified as nonsmoker versus current smoker and nondrinker versus current drinker based on self-report.

The dependent variable in this study was patient adherence to CPAP for managing OSA post-stroke, which was operationally defined as use of a CPAP device for at least 4 h per night for at least 70% of the nights during the follow-up period. The primary follow-up time point was 6 months after initiation of CPAP (i.e., investigating short-term adherence) and the secondary follow-up time point was 12 months after initiation of CPAP (i.e., investigating longer term adherence). Utilization data were automatically recorded via the CPAP devices.

3.3 | Data collection

A poster describing the research project was placed in the stroke unit. A designated physician assisted in the recruitment process by screening and referring eligible patients to the first author. The first author then provided patients with detailed information about the research project and invited them to participate. After obtaining written informed consent, data collection began. Participant socio-demographic and clinical information were obtained from the electronic health record. Clinical diagnosis and severity evaluation of stroke, OSA, as well as comorbid hypertension and type 2 diabetes were identified by the designated physician; while assessments of swallowing function and dependence in activities of daily living were performed by a designated nurse specialist. The first author measured BMI as well as neck and waist circumferences of participants. In order to minimize measurement error, participants were requested to remove heavy coats and shoes before undergoing height and weight measurements for BMI calculation, and the tape measure for neck and waist circumference measurements was calibrated before use. The Health Belief Scale and ESS were completed by participants. Baseline data collection was conducted at the stroke unit, with the exception of the PSG indices, which were collected at the sleep medicine center.

The CPAP was initiated after completing baseline data collection. Pressure of CPAP was first titrated by a sleep specialist to determine treatment parameters, then participants were instructed to maintain CPAP for no less than 4 h per night. Daily records of CPAP utilization were automatically uploaded from treatment devices to a dedicated web-based platform. Researchers logged into the platform and downloaded data for participants at 6 months after initiation of CPAP. Data on CPAP utilization that indicated good adherence during the 6-month follow-up period were then collected at 12 months after initiation of CPAP. Data collection was completed in June 2023. The flow diagram of this study is depicted in Figure 2.

3.4 | Data analysis

Data analysis was performed using SPSS 23.0 software for Windows (IBM Corporation, Armonk, NY). Shapiro–Wilk test and Q-Q plots were used to determine the distribution pattern of the independent variable data. Normally distributed continuous variables were expressed using means and standard deviations (SD), while skewed continuous variables were presented as medians and interquartile ranges (IQR). Nominal and categorical variables were expressed as frequencies and percentages. Univariate analysis was performed using *t*-tests, Mann–Whitney *U* tests, Chi-square tests, or Fisher's exact tests, depending on the type and distribution of variable data, to explore differences between CPAP adherent and non-adherent groups regarding predisposing factors, enabling factors, need factors, and personal health practices. Multivariate logistic regression analysis was then performed on the variables that showed statistically significant differences in the univariate analysis to identify independent factors predicting adherence to CPAP in patients with OSA post-stroke. Collinearity of included variables was assessed according to the corresponding variance inflation factors (VIF), with values below five being regarded as tolerable. Results of multivariate logistic regression analysis were presented as odds ratios (OR) and corresponding 95% confidence intervals (CI). The significance level for all statistical analyses was set at $p < 0.05$.

3.5 | Ethical considerations

The study was approved by the ethics review committee of Huazhong University of Science and Technology Union Shenzhen Hospital, Shenzhen, Guangdong Province, China (reference number: KY-2020-

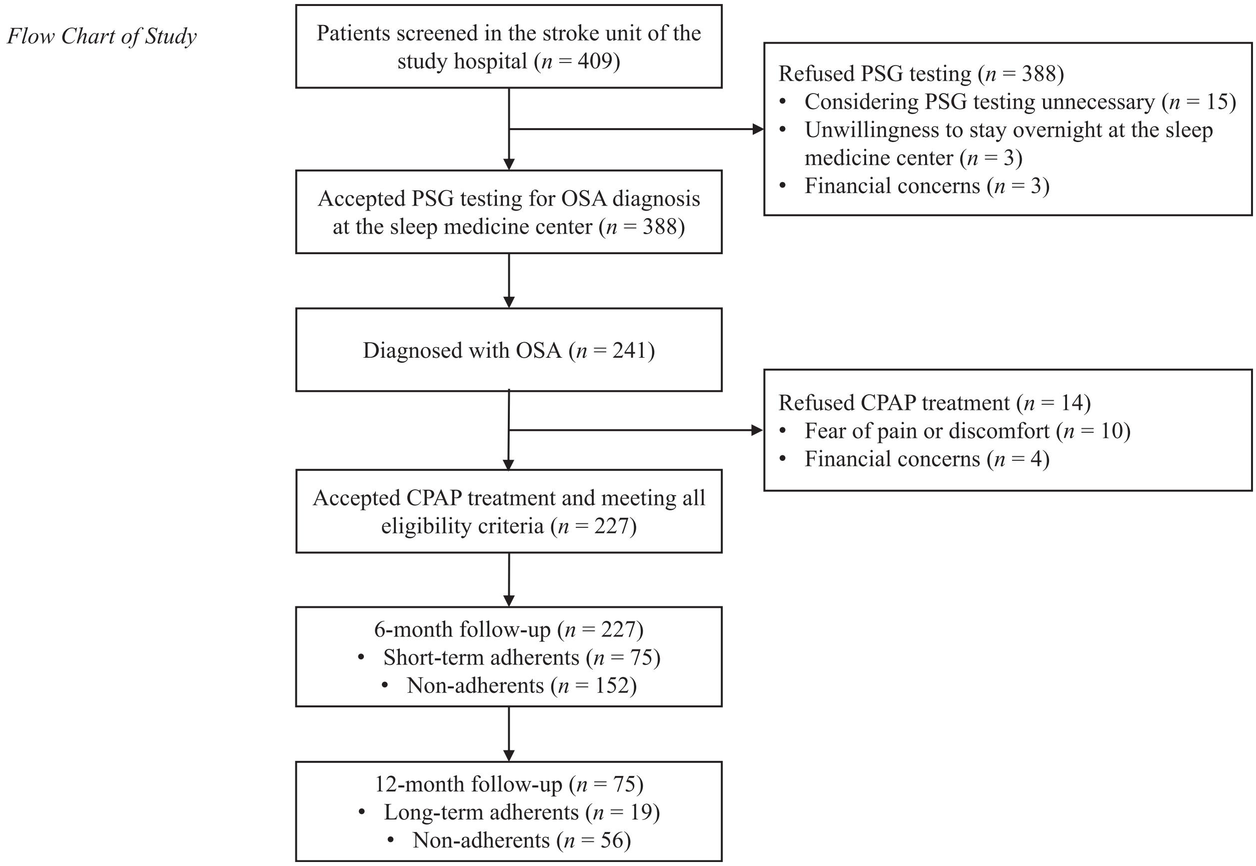

FIGURE 2 Flow chart of study. CPAP, continuous positive airway pressure; OSA, obstructive sleep apnea; PSG, polysomnography.

047-01). Participants were informed of their right to withdraw from the study at any time without prejudice. Written informed consent was obtained from all participants.

4 | RESULTS

4.1 | Participant characteristics

Initially, 409 patients with stroke admitted to the stroke unit of the study hospital were approached, of which 388 received clinical assessments and PSG testing for OSA diagnosis at the sleep medicine center. A total of 241 patients with stroke received a confirmed diagnosis of OSA according to the pre-specified criteria and were prescribed CPAP. Fourteen (6%) patients refused CPAP, resulting in the inclusion of 227 participants who agreed to receive CPAP. Most participants were male ($n = 195$, 86%), with a median age of 51 (IQR, 44–59) years. Participants aged ≥60 years ($n = 55$) accounted for 24% of the total sample. Sixty-six percent ($n = 150$) of participants had comorbid hypertension, while 29% ($n = 67$) had comorbid type 2 diabetes. As measured using the ESS, 23% ($n = 53$) of participants experienced excessive daytime sleepiness. Other socio-demographic and clinical data are shown in Table 1.

4.2 | Factors influencing short-term adherence to CPAP

Only 75 (33%) participants were identified as having good adherence while 152 (67%) showed poor adherence to prescribed CPAP at 6-month follow-up. Differences between the CPAP adherent and non-adherent groups related to predisposing factors are presented in Table 2. Univariate analysis showed no statistically significant differences between the two groups in gender ($p = 0.15$) and religion ($p = 0.62$). Participants in the adherent group were more likely to be older ($p = 0.049$), married or living with a partner ($p = 0.003$), better educated ($p = 0.023$), and having stronger health beliefs about the benefit of CPAP on OSA post-stroke ($p < 0.001$). In terms of enabling factors (Table 2), no significant difference was found between the two groups in employment status ($p = 0.27$) and monthly household income ($p = 0.15$).

Table 2 demonstrates the differences between the CPAP adherent and non-adherent groups regarding need factors and personal health practices. Univariate analysis demonstrated that, compared with the non-adherent group, the adherent group had more severe stroke as measured using the NIHSS ($p = 0.001$) and poorer OSA indices including AHI ($p = 0.008$) and average oxygen saturation ($p = 0.031$) at diagnosis. There were no statistically significant

TABLE 1 Socio-demographic and clinical characteristics of participants.

Variable	Value	Variable	Value
Predisposing factors		Need factors	
Gender, *n* (%)		ESS score, median [IQR]	6.0 [0, 8.0]
Male	195 (85.9%)	Body mass index, *n* (%)	
Female	32 (14.1%)	<18.5 kg/m^2	3 (1.3%)
Age (years), median [IQR]	51.0 [45.0, 59.0]	18.6–22.9 kg/m^2	30 (13.2%)
Marital status, *n* (%)		23–24.9 kg/m^2	58 (25.6%)
Single/widow	72 (31.7%)	≥25 kg/m^2	136 (59.9%)
Married/living with partner	155 (68.3%)	Hypertension, *n* (%)	
Education level, *n* (%)		Yes	150 (66.1%)
Primary school or below	80 (35.2%)	No	77 (33.9%)
Secondary school	47 (20.7%)	Diabetes, *n* (%)	
Associate degree	63 (27.8%)	Yes	67 (29.5%)
Baccalaureate degree or higher	37 (16.3%)	No	160 (70.5%)
Religion, *n* (%)		Neck circumference (cm), median [IQR]	41.0 [38.0, 42.0]
Yes	8 (3.5%)	Waist circumference (cm), median [IQR]	102.0 [97.0, 105.0]
No	219 (96.5%)	NIHSS score, median [IQR]	3.0 [1.0, 4.0]
Health Belief Scale score, median [IQR]	52.0 [48.0, 58.0]	Apnea–hypopnea index, median [IQR]	23.0 [11.5, 37.5]
Enabling factors		Maximum apnea duration (s), median [IQR]	48.0 [29.5, 69.0]
Employment status, *n* (%)		Minimum oxygen saturation, median [IQR]	85.0% [78.0%, 90.0%]
Employed	119 (52.4%)	Average oxygen saturation, median [IQR]	96.0% [95.0%, 97.0%]
Unemployed	48 (21.1%)	Swallowing dysfunction, *n* (%)	
Retired	60 (26.4%)	Yes	32 (14.1%)
Monthly household income, *n* (%)		No	195 (85.9%)
<10 000 CNY	11 (4.8%)	Modified Barthel index, median [IQR]	92.0 [85.0, 100.0]
10 000–29 999 CNY	131 (57.7%)	Personal health practices	
30 000–59 999 CNY	65 (28.6%)	Current drinker, *n* (%)	
>60 000 CNY	20 (8.8%)	Yes	149 (65.6%)
		No	78 (34.4%)
		Current smoker, *n* (%)	
		Yes	87 (38.35%)
		No	140 (61.7%)

Abbreviations: CNY, Chinese Yuan Renminbi; ESS, Epworth Sleepiness Scale; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale.

differences between the two groups in daytime sleepiness, BMI, neck and waist circumferences, minimum oxygen saturation, maximum apnea duration, swallowing function, dependence in activities of daily living, as well as comorbid hypertension and type 2 diabetes at diagnosis (all $p > 0.05$). The adherent group had a slightly higher proportion of current smokers than the non-adherent group (41% vs. 37%), while the non-adherent group had a slightly higher proportion of current drinkers than the adherent group (68% vs. 61%). However, univariate analysis identified no significant differences between the adherent and non-adherent groups in smoking and drinking behaviors (all $p > 0.05$).

Variables that were statistically significant in univariate analysis were entered in multivariate logistic regression analysis. The VIF values of included variables ranged between 1.070 and 1.196 (all VIF values <5), suggesting no significant multicollinearity. Results of multivariate analysis showed that marital status, education level, and health beliefs on CPAP were independent factors predicting short-term adherence to CPAP in patients with OSA post-stroke. Specifically, participants who were married or living with a partner had better adherence to CPAP compared with those who were single (OR = 6.27, 95% CI: 2.24–17.54, $p < 0.001$). Participants with an associate degree (OR = 4.34, 95% CI: 1.50–12.61, $p = 0.007$) and those with baccalaureate degrees or higher (OR = 8.23, 95% CI: 1.96–34.54, $p = 0.004$) were more likely to adhere to CPAP than those with primary school education or less. Stronger health beliefs predicted greater adherence to CPAP (OR = 1.33, 95% CI: 1.23 to 1.45, $p < 0.001$). Detailed results are presented in Table 3.

TABLE 2 Univariate analysis of factors associated with short-term adherence to continuous positive airway pressure (CPAP) in patient with obstructive sleep apnea post-stroke.

	6 months follow-up (*n* = 227)			
Variable	**CPAP adherent (*n* = 75)**	**CPAP non-adherent (*n* = 152)**	**Statistics**	***p* Value**
Predisposing factors				
Gender, *n* (%)			$\chi^2 = 2.099$	0.15
Male	68 (90.7%)	127 (83.6%)		
Female	7 (9.3%)	25 (16.4%)		
Age (years), median [IQR]	51.0 [41.0, 55.0]	53.0 [46.0, 60.0]	$Z = -1.966$	0.049
Marital status, *n* (%)			$\chi^2 = 8.809$	0.003
Single/widow	14 (18.7%)	58 (38.2%)		
Married/living with partner	61 (81.3%)	94 (61.8%)		
Education level, *n* (%)			$\chi^2 = 9.573$	0.023
Primary school or below	18 (24.0%)	62 (40.8%)		
Secondary school	14 (18.7%)	33 (21.7%)		
Associate degree	25 (33.3%)	38 (25.0%)		
Baccalaureate degree or above	18 (24.0%)	19 (12.5%)		
Religion, *n* (%)			$\chi^2 = 0.012$	>0.90
Yes	2 (2.7%)	6 (3.9%)		
No	73 (97.3%)	146 (96.1%)		
Health Belief Scale score, median [IQR]	59.0 [55.0, 64.0]	49.0 [45.0, 53.5]	$Z = -9.091$	<0.001
Enabling factors				
Employment status, *n* (%)			$\chi^2 = 2.588$	0.27
Employed	44 (58.7%)	75 (49.3%)		
Unemployed	16 (21.3%)	32 (21.1%)		
Retired	15 (20.0%)	45 (29.6%)		
Monthly household income, *n* (%)			$\chi^2 = 4.154$	0.25
<10 000	4 (5.3%)	7 (4.6%)		
10 000–29 999	40 (53.4%)	91 (59.9%)		
30 000–59 999	27 (36.0%)	38 (25.0%)		
>60 000	4 (5.3%)	16 (10.5%)		
Need factors				
ESS, median [IQR]	7.0 [0, 10.0]	5.0 [0, 8.0]	$Z = -0.863$	0.39
BMI (kg/m^2), *n* (%)			-[a]	0.058
<18.5 kg/m^2	1 (1.3%)	2 (1.3%)		
18.6–22.9 kg/m^2	4 (5.3%)	26 (17.1%)		
23–24.9 kg/m^2	19 (25.4%)	39 (25.7%)		
≥25 kg/m^2	51 (68.0%)	85 (55.9%)		
Hypertension, *n* (%)			$\chi^2 = 1.752$	0.19
Yes	54 (72.0%)	96 (63.2%)		
No	21 (28.0%)	56 (36.8%)		
Diabetes, *n* (%)			$\chi^2 = 0.332$	0.56
Yes	24 (32.0%)	43 (28.3%)		
No	51 (68.0%)	109 (71.7%)		
Neck circumference (cm), median [IQR]	40.0 [38.0, 42.0]	41.0 [38.0, 42.0]	$Z = -1.067$	0.29
Waist circumference (cm), median [IQR]	102.0 [97.0, 109.0]	101.0 [96.0, 105.0]	$Z = -1.432$	0.15
NIHSS, median [IQR]	4.0 [2.0, 5.0]	2.0 [1.0, 3.8]	$Z = -3.177$	0.001
Apnea–hypopnea index, median [IQR]	15.5 [9.1, 32.3]	28.9 [12.2, 38.4]	$Z = -2.643$	0.008

(Continues)

TABLE 2 (Continued)

Variable	6 months follow-up ($n = 227$) CPAP adherent ($n = 75$)	CPAP non-adherent ($n = 152$)	Statistics	*p* Value
Maximum apnea duration (s), median [IQR]	48.0 [27.5, 71.0]	49.0 [30.0, 66.0]	$Z = -0.186$	0.85
Minimum oxygen saturation, median [IQR]	84.0%[74.0%, 89.0%]	86.0% [80.3%, 90.0%]	$Z = -1.740$	0.082
Average oxygen saturation, median [IQR]	95.0% [94.0%, 97.0%]	96.0% [95.0%, 97.5%]	$Z = -2.158$	0.031
Swallowing dysfunction, *n* (%)			$\chi^2 = 2.099$	0.15
Yes	7 (9.3%)	25 (16.4%)		
No	68 (90.7%)	127 (83.6%)		
Modified Barthel index, median [IQR]	92.0 [85.0, 100.0]	92.0 [85.0, 100.0]	$Z = -0.282$	0.78
Personal health practices				
Current drinker, *n* (%)			$\chi^2 = 0.921$	0.34
Yes	46 (61.3%)	103 (67.8%)		
No	29 (38.7%)	49 (32.2%)		
Current smoker, *n* (%)			$\chi^2 = 0.429$	0.51
Yes	31 (41.3%)	56 (36.8%)		
No	44 (58.7%)	96 (63.2%)		

Abbreviations: BMI, body mass index; ESS, Epworth Sleepiness Scale; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale.
[a]Fisher's exact test was used.

TABLE 3 Multivariate logistic regression for predictors of short-term adherence to continuous positive airway pressure in patients with obstructive sleep apnea post-stroke during 6 months follow-up.

Variable	Beta	Standard error	Wald	Odds ratio	95% confidence interval	*p* Value	Variance inflation factor
Predisposing factors							
Age	−0.020	0.018	1.223	0.98	0.95–1.02	0.27	1.196
Marital status							1.120
Single/widow (reference)							
Married/living with partner	1.836	0.524	12.264	6.27	2.24–17.54	<0.001	
Education level							1.160
Primary school or below (reference)							
Secondary school	0.325	0.584	0.310	1.384	0.44–4.34	0.578	
Associate degree	1.469	0.544	7.298	4.344	1.50–12.61	0.007	
Baccalaureate degree or higher	2.108	0.732	8.295	8.230	1.96–34.54	0.004	
Health Belief Scale score	0.288	0.041	48.409	1.333	1.23–1.45	<0.001	1.122
Need factors							
NIHSS score	0.108	0.075	2.093	1.114	0.96–1.29	0.15	1.070
Apnea–hypopnea index	−0.019	0.012	2.424	0.981	0.96–1.00	0.12	1.083
Average oxygen saturation	−0.079	0.107	0.545	0.924	0.75–1.14	0.46	1.073

Abbreviation: NIHSS, National Institutes of Health Stroke Scale.

4.3 | Factors influencing long-term adherence to CPAP

Data on long-term adherence to CPAP at 12-month follow-up were available from the 75 participants with good short-term adherence. Only 19 (25%) maintained good adherence to CPAP between 6- and 12-month follow-up according to the pre-specified criteria (use of the CPAP for ≥4 h per night for at least 70% of the nights during the follow-up period). At this point, the adherence rate based on the total sample was 8%. Exploratory univariate analysis revealed that only alcohol consumption behavior was significantly associated with longer term CPAP adherence, that is, participants who consistently maintained good adherence to CPAP for 12 months were more likely to be nondrinkers (Table 4). However, researchers were unable to

TABLE 4 Univariate analysis of factors associated with long-term adherence to continuous positive airway pressure (CPAP) in patient with obstructive sleep apnea post-stroke.

Variable	12 months follow-up ($n = 75$) CPAP adherent ($n = 19$)	CPAP non-adherent ($n = 56$)	Statistics	p Value
Predisposing factors				
Gender, n (%)			$\chi^2 = 0.062$	0.80
Male	18 (94.7%)	50 (89.3%)		
Female	1 (5.3%)	6 (10.7%)		
Age (years), median [IQR]	51.0 [41.0, 62.0]	51.0 [41.5, 54.0]	$Z = -0.396$	0.69
Marital status, n (%)			$\chi^2 = 0.422$	0.52
Single/widow	5 (26.3%)	9 (16.1%)		
Married/living with partner	14 (73.7%)	47 (83.9%)		
Education level, n (%)			-[a]	0.76
Primary school or below	4 (21.1%)	14 (25.0%)		
Secondary school	5 (26.3%)	9 (16.1%)		
Associate degree	5 (26.3%)	20 (35.7%)		
Baccalaureate degree or above	5 (26.3%)	13 (23.2%)		
Religion, n (%)			-[a]	>0.90
Yes	0 (0%)	2 (3.6%)		
No	19 (100.0%)	54 (96.4%)		
Health Belief Scale score, median [IQR]	58.0 [55.0, 64.0]	59.0 [55.0, 62.8]	$Z = -0.018$	>0.90
Enabling factors				
Employment status, n (%)			-[a]	0.36
Employed	10 (52.6%)	34 (60.7%)		
Unemployed	3 (15.8%)	13 (23.2%)		
Retired	6 (31.6%)	9 (16.1%)		
Monthly household income, n (%)			-[a]	0.31
<10 000	0 (0%)	4 (7.1%)		
10 000–29 999	12 (63.2%)	28 (50.0%)		
30 000–59 999	5 (26.3%)	22 (39.3%)		
>60 000	2 (10.5%)	2 (3.6%)		
Need factors				
ESS, median [IQR]	3.0 [0, 10.0]	7.0 [0, 10.0]	$Z = -0.588$	0.56
BMI (kg/m^2), n (%)			-[a]	0.30
<18.5 kg/m^2	1 (5.3%)	0 (0%)		
18.6–22.9 kg/m^2	0 (0%)	4 (7.1%)		
23–24.9 kg/m^2	4 (21.0%)	15 (26.8%)		
≥25 kg/m^2	14 (73.7%)	37 (66.1%)		
Hypertension, n (%)			$\chi^2 = 0.609$	0.44
Yes	15 (78.9%)	39 (69.6%)		
No	4 (21.1%)	17 (30.4%)		
Diabetes, n (%)			$\chi^2 = 0.274$	0.60
Yes	7 (36.8%)	17 (30.4%)		
No	12 (63.2%)	39 (69.6%)		
Neck circumference (cm), median [IQR]	39.0 [38.0, 41.0]	40.5 [38.0, 42.0]	$Z = -1.208$	0.23
Waist circumference (cm), median [IQR]	102.0 [98.0, 105.0]	102.0 [97.0, 110.0]	$Z = -0.575$	0.57
NIHSS, median [IQR]	2.0 [1.0, 5.0]	4.0 [2.0, 6.0]	$Z = -1.295$	0.20
Apnea–hypopnea index, median [IQR]	12.9 [7.9, 24.9]	15.7 [9.8, 33.7]	$Z = -0.902$	0.37

(Continues)

TABLE 4 (Continued)

Variable	12 months follow-up ($n = 75$) CPAP adherent ($n = 19$)	CPAP non-adherent ($n = 56$)	Statistics	p Value
Maximum apnea duration (s), median [IQR]	49.9 [27.5, 75.0]	47.8 [27.6, 67.3]	$Z = -0.652$	0.51
Minimum oxygen saturation, median [IQR]	82.0% [73.0%, 91.0%]	84.5% [74.5%, 89.0%]	$Z = -0.085$	>0.90
Average oxygen saturation, median [IQR]	95.0% [94.0%, 97.0%]	95.0% [94.3%, 96.8%]	$Z = -0.229$	0.82
Swallowing dysfunction, n (%)			$\chi^2 = 0.062$	0.80
Yes	1 (5.3%)	6 (10.7%)		
No	18 (94.7%)	50 (89.3%)		
Modified Barthel index, median [IQR]	90.0 [86.0, 98.0]	92.0 [85.0, 100.0]	$Z = -0.031$	>0.90
Personal health practices				
Current drinker, n (%)			$\chi^2 = 5.616$	0.018
Yes	16 (84.2%)	30 (53.6%)		
No	3 (15.8%)	26 (46.4%)		
Current smoker, n (%)			$\chi^2 = 0.998$	0.32
Yes	6 (31.6%)	25 (44.6%)		
No	13 (68.4%)	31 (55.4%)		

Abbreviations: BMI, body mass index; ESS, Epworth Sleepiness Scale; IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale.
[a]Fisher's exact test was used.

assess changes in the severity of stroke and OSA, dependence in activities of daily living, and health beliefs or examine their association with adherence to CPAP.

5 | DISCUSSION

Although the use of CPAP can reduce the risk of adverse health consequences in patients with OSA post-stroke, adherence to CPAP remains challenging. Identifying key factors influencing patient adherence based on the Andersen model could inform the development of theory-driven interventions to promote CPAP utilization for management of OSA post-stroke. To the researchers' knowledge, this is the largest real-world prospective study of CPAP adherence conducted with Chinese patients having OSA post-stroke. Ninety-four percent of the participants purchased a device to initiate CPAP; this rate is higher than the 84.5% reported in a previous real-world study conducted in Canada (Kendzerska et al., 2019). However, only 33% of patients maintained good adherence at 6-month follow-up after initiation of CPAP, a rate that is at the low end of the range between 30% and 60% reported in former studies. During longer term follow-up, a considerable number of patients who previously performed well became non-adherent, resulting in lower adherence to CPAP at 12 months compared with previous studies. This is in contrast to Kendzerska et al.'s (2019) findings that a majority of patients who had good short-term adherence would also maintain longer term adherence. A possible explanation for this discrepancy is that diagnosis and management of OSA post-stroke are currently not a common practice in China and there is a lack of systematic patient education and clinical management programs to address treatment adherence. Similar findings were found in a large international trial where Chinese patients with OSA and cardiovascular disease showed lower adherence to CPAP at 24 months follow-up compared with patients from high-income countries such as Australia and New Zealand (Van Ryswyk et al., 2019).

Following the Andersen model, the current study found that it was predisposing factors rather than enabling and need factors that had a significant impact on adherence to CPAP. Being married or living with a partner was a favorable factor for patient adherence to CPAP. Although this factor has not been considered in previous studies specific to patients with OSA post-stroke, a similar association was observed in a study involving general patients with OSA (Palm et al., 2021). This is presumably due to the fact that a spouse or partner who sleeps with the patient is able to detect symptoms associated with OSA, such as snoring, and provides feedback to the patient on benefits of CPAP (Palm et al., 2021). Although the study by Kendzerska et al. (2019) did not include marital status in the analysis, it suggested that family support can predict adherence to CPAP in patients with OSA post-stroke; this finding may indirectly support the value of spousal or partner support. Engaging spouses, partners, or other close family members in patient adherence management becomes meaningful.

Although this study found that the non-adherent group had a significantly higher median age than the adherent group in the univariate analysis, subsequent multivariate analysis showed that age was not an independent predictor for adherence to CPAP in patients with OSA post-stroke. In contrast, Kendzerska et al. (2019) found that younger age predicts better adherence to CPAP. This may be partly due to the fact that the majority of the sample included in the current study were younger patients, whereas less than a quarter of the patients were aged 60 years or above; this makes it difficult to identify the association of age with patient adherence to CPAP when the effect size is small. Indeed, age itself is a somewhat controversial factor. For instance, the study by Colelli et al. (2020) also showed that age was not associated with adherence to CPAP in patients with OSA post-stroke, despite the similar median age between their sample and that of Kendzerska et al. In light of the current study findings and the evidence from previous research (MacDonald et al., 2020), it can be hypothesized that age is more important in influencing patient willingness to receive PSG testing for the diagnosis of OSA. Therefore, more attention is needed to the underdiagnosis of OSA in elderly patients.

This study also found that better educated patients, especially those with advanced degrees, showed greater adherence to CPAP. This finding echoes a previous study involving patients with OSA, which identified education level as a significant socioeconomic factor associated with disparities in CPAP adherence (Palm et al., 2021). Possible mechanisms for the impact of education level on CPAP adherence could include the fact that highly educated patients are more likely to have access to and comprehend information pertaining to OSA and CPAP. Additionally, they may possess better communication skills, enabling them to consult and engage with health professionals or industry technicians to address any challenges encountered while using CPAP devices. Those with low educational attainment, on the other hand, may not have sufficient knowledge and skills to acquire information for solving practical problems when using CPAP, nor can they comprehend the risk of OSA and the benefits of CPAP, leading to poor adherence. Since previous studies have not analyzed the influence of education level on adherence to CPAP in patients with OSA post-stroke, the current findings need to be validated in future research.

This study adds to the literature by showing that patients with stronger health beliefs about CPAP for the management of OSA post-stroke are more likely to adhere to the prescribed treatment. This finding has similarities to a previous study where a health belief model predicted adherence to CPAP in patients with OSA (Olsen et al., 2008). Since health beliefs are a modifiable factor, developing and implementing interventions to enhance health beliefs in patients with OSA post-stroke may help improve adherence to CPAP, thereby optimizing health outcomes (Crosby et al., 2023; Jones et al., 2014). Further research is warranted to examine the role and mechanisms of health beliefs and their dimensions in patient adherence to CPAP by using structural equation modeling to inform the design of theory-driven interventions.

There was no significant correlation between monthly household income, the only enabling factor included, and adherence to CPAP in patients with OSA post-stroke. This may be due to the fact that the participants included in this study were generally in a better financial situation and for whom CPAP was affordable. It is important to note that 14 patients refused CPAP during the recruitment phase. The researchers were not able to comprehensively evaluate these patients to obtain research data and examine whether there was a significant difference in financial status between patients who accepted or refused CPAP. This might be a point of concern as CPAP is not covered by health insurance in China. A patient's financial status might determine whether they can afford to pay out-of-pocket for a CPAP device. Future studies could consider inviting patients who refused CPAP to participate in an in-depth interview to better understand barriers to CPAP use and to develop individualized patient support programs.

In terms of health need factors, multivariate analysis results demonstrated that effects of stroke and OSA severity on patient adherence to CPAP have been buffered by predisposing factors. Kendzerska et al. (2019) concluded that the severity of stroke-induced deficits can affect patient adherence to CPAP, while family support can help patients overcome negative effects of stroke-induced deficits. Thus, it may be worthwhile to explore whether spousal, partner and family support mediate the relationship between stroke-induced deficits and adherence to CPAP in patients with OSA post-stroke. In the current study, average oxygen saturation was not an independent predictor for adherence to CPAP in patients with OSA post-stroke. Similarly, a prior study found that average oxygen saturation is a predictor of whether or not to purchase a CPAP device rather than adherence to CPAP (Kendzerska et al., 2019). Consistent with Kendzerska et al.'s (2019) and Colelli et al.'s (2020) studies, current findings do not support that AHI is a predictor of adherence to CPAP in patients with OSA post-stroke; this may be due to the level of AHI not necessarily matching the severity of OSA symptoms perceived by patients with stroke.

Patients' health behavior may have an impact on their long-term adherence to CPAP. In this study, patients consuming alcohol showed a decrease in adherence to CPAP after 6-month follow-up. However, Van Ryswyk et al. (2019) did not find that alcohol drinking habits affected long-term adherence to CPAP in patients with OSA and cardiovascular disease over a 24-month follow-up period. The two studies (Colelli et al., 2020; Kendzerska et al., 2019) specifically involving patients with OSA post-stroke did not include alcohol consumption in their analyses. Smoking habit was found to be significantly associated with poor long-term adherence in patients with OSA post-stroke by Kendzerska et al. (2019), whereas this was not the case in the current findings. Although the current research was unable to provide consistent evidence to determine a causal relationship between certain lifestyle behaviors and patient adherence to CPAP, findings do suggest that lifestyle modification should be considered as an intervention component to address long-term adherence to CPAP.

It has to be acknowledged that this study has several limitations. It was conducted in a single center and included a large proportion of younger participants (<60 years), making the results insufficiently generalizable to the entire population of patients with OSA post-stroke. However, the study sample reflects the characteristics of OSA practice previously reported in the literature, namely that older patients are often underdiagnosed due to their reluctance to undergo PSG testing; this provides important lessons for real-world practice. In addition, the independent and dependent variables encompassed a variety of clinical assessments, anthropometric measurements, and patient-reported outcomes, which allowed for potential measurement error. This could have increased the risk of biased regression coefficients, underestimated predictor variables, and misclassified participants. However, the current study utilized well-trained personnel to conduct data collection using reliable instruments and applied BMI classification thresholds suitable for Asian populations, ensuring that the impact of measurement error was minimized. Another limitation was the use of a design rooted in a real-world practice setting as it did not continuously assess the changes in participants' neurological functioning, OSA symptoms, and health beliefs over the follow-up period, thus making it difficult to determine the dynamic interactions between these changes and patient adherence to CPAP. Furthermore, patients who were unwilling to undergo PSG testing or CPAP treatment were excluded during the screening phase. These patients may represent a group that did not receive effective OSA management. While the exclusion of these patients did not result in missing data for the current study, it may have overlooked certain factors that could potentially influence CPAP utilization. Future studies should focus on patients who refuse PSG testing or CPAP treatment at baseline. Finally, due to the sample size, there were limitations to including more system-level factors in the analysis. However, patient adherence to CPAP should be largely influenced by patient-centered factors. The independent variables that were included served the purpose of identifying key modifiable factors at the patient level. No multicollinearity was found among these independent variables, indicating the robustness of the analysis results in the current study.

6 | CONCLUSION

This prospective study revealed suboptimal adherence to CPAP in patients with OSA post-stroke. Based on the Andersen model, predisposing factors including marital status, education level, and health beliefs were significantly associated with patient adherence to CPAP. These results support a theory-driven approach to promote CPAP utilization in patients with OSA post-stroke by targeting unfavorable predisposing factors and modifying health beliefs.

6.1 | Relevance for clinical practice

Nurses should provide patients with easy-to-understand education soon after a diagnosis of OSA, which would help increase health literacy and beliefs on CPAP for the management of OSA post-stroke. Encouraging spouses or family members to participate in patient management is also important. For patients living alone, it would be important to provide them with individualized support interventions or liaise them with peer-support resources. During long-term follow-up, nurses can collaborate with family health practitioners to optimize patients' health beliefs and lifestyles through motivational interviewing and lifestyle coaching, which may promote patient adherence to CPAP.

AUTHOR CONTRIBUTIONS

Hua-Lu Yang: Conceptualization; methodology; investigation; formal analysis; project administration; writing – original draft; writing – review and editing; data curation. **Mian Wang:** Conceptualization; methodology; formal analysis; supervision; writing – original draft; writing – review and editing; data curation. **Yan-Fei Xu:** Conceptualization; resources; writing – review and editing. **Bei-Rong Mo:** Conceptualization; writing – review and editing. **Xian-Liang Liu:** Conceptualization; funding acquisition; writing – review and editing. **Sharon R. Redding:** Writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY STATEMENT

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

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APPENDIX

	使用持续气道正压通气治疗脑卒中后阻塞性睡眠呼吸暂停的健康信念量表 (Health belief scale on continuous positive airway pressure treatment for obstructive sleep apnea post-stroke)					
	根据您对阻塞性睡眠呼吸暂停及持续气道正压通气治疗的理解和感知，请从以下表述中选择最适合您本人的选项，并在对应空格内打"√"。 (Based on your understanding and perception of obstructive sleep apnea and continuous positive airway pressure treatment, please select the option that best fits yourself from the following statements and mark it with a "√" in the corresponding space.)					
	感知到的易感性 Perceived susceptibility	非常 不同意 Strongly disagree	不同意 Disagree	不确定/中立 Not sure/ neutral	同意 Agree	非常 同意 Strongly agree
1	我的阻塞性睡眠呼吸暂停症状会一直持续 My obstructive sleep apnea symptoms will persist					
2	我在未来几年内脑卒中复发的几率很高 My chances of getting recurrent stroke in the next few years are high					
	感知到的严重性 Perceived severity	非常 不同意 Strongly disagree	不同意 Disagree	不确定/中立 Not sure/ neutral	同意 Agree	非常 同意 Strongly agree
3	患上阻塞性睡眠呼吸暂停影响我的家庭生活 Having obstructive sleep apnea affects my family life					
4	患上阻塞性睡眠呼吸暂停使我的日常活动更加困难 Having obstructive sleep apnea makes my daily activities more difficult					
5	管理不佳的阻塞性睡眠呼吸暂停将导致脑卒中病情恶化或复发 Poorly managed obstructive sleep apnea can lead to a worsening or recurrence of stroke					
	感知到的持续气道正压通气治疗的益处	非常 不同意 Strongly disagree	不同意 Disagree	不确定/中立 Not sure/ neutral	同意 Agree	非常 同意 Strongly agree
6	接受持续气道正压通气治疗可以防止我的阻塞性睡眠呼吸暂停加重 Continuous positive airway pressure treatment prevents my obstructive sleep apnea from getting worse					
7	持续气道正压通气治疗可以帮助预防脑卒中复发 Continuous positive airway pressure treatment can help prevent stroke recurrence					
8	持续气道正压通气治疗可以提高我白天的警觉性 Continuous positive airway pressure treatment improves my daytime vigilance					
9	接受持续气道正压通气治疗可以减小我的鼾症给我的配偶/伴侣/家人带来的影响 Continuous positive airway pressure treatment reduces the impact of my snoring symptom on my spouse/partner and/or family					
	感知到接受持续气道正压通气治疗的障碍 Perceived barriers to receiving continuous positive airway pressure treatment	非常 不同意 Strongly disagree	不同意 Disagree	不确定/中立 Not sure/ neutral	同意 Agree	非常 同意 Strongly agree
10	我担心持续气道正压通气治疗会引起疼痛 I am afraid that continuous positive airway pressure treatment will cause pain					
11	我担心使用持续气道正压通气设备会让我难以入睡 I am worried that using continuous positive airway pressure device will make it difficult for me to fall asleep					

使用持续气道正压通气治疗脑卒中后阻塞性睡眠呼吸暂停的健康信念量表 (Health belief scale on continuous positive airway pressure treatment for obstructive sleep apnea post-stroke)

根据您对阻塞性睡眠呼吸暂停及持续气道正压通气治疗的理解和感知，请从以下表述中选择最适合您本人的选项，并在对应空格内打"√"。(Based on your understanding and perception of obstructive sleep apnea and continuous positive airway pressure treatment, please select the option that best fits yourself from the following statements and mark it with a "√" in the corresponding space.)

12	我担心持续气道正压通气治疗会引起副作用 I am afraid that continuous positive airway pressure treatment will induce side effects					
13	接受持续气道正压通气治疗会带来经济压力 Receiving continuous positive airway pressure treatment can be financially stressful					
14	接受持续气道正压通气治疗过程中缺乏专业指导 No professional guidance is available during continuous positive airway pressure treatment					
15	持续气道正压通气治疗与我的工作和生活习惯相冲突 Continuous positive airway pressure treatment conflicts with my work and lifestyle habits					
	健康动力 Cue to action	非常不同意 Strongly disagree	不同意 Disagree	不确定/中立 Not sure/neutral	同意 Agree	非常同意 Strongly agree
16	在医生/家人/朋友的建议下，我决定接受持续气道正压通气治疗 With the advice and/or encouragement of my doctor, spouse, partner, family, and/or friends, I decided to receive continuous positive airway pressure treatment					
	自我效能 Self-efficacy	非常不同意 Strongly disagree	不同意 Disagree	不确定/中立 Not sure/neutral	同意 Agree	非常同意 Strongly agree
17	我知道如何正确使用持续气道正压通气设备 I know how to properly use a continuous positive airway pressure device					
18	我有信心能遵医嘱自我开展持续气道正压通气治疗 I am confident that I can self-administer continuous positive airway pressure treatment as prescribed by my physician					
19	我相信我能通过从可靠来源获得有用信息和实际支持来解决持续气道正压通气治疗中出现的困难 I believe I can address difficulties that arise during continuous positive airway pressure treatment through obtaining useful information and practical support from reliable sources					