



Predictors of Continuous Positive Airway Pressure Adherence and Comparison of Clinical Factors and Polysomnography Findings Between Compliant and Non-Compliant Korean Adults With Obstructive Sleep Apnea

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Objective Continuous positive airway pressure (CPAP) is the preferred treatment for obstructive sleep apnea (OSA). However, compliance with CPAP therapy varies among studies, and studies on its predictors are insufficient in Korea. This study aimed to identify factors that predict compliance with CPAP therapy in patients with OSA.

Methods We retrospectively reviewed medical records, polysomnography (PSG) records, and self-report questionnaires of patients with OSA. Criteria for compliance was the use of CPAP devices for ≥ 4 h per night for $\geq 70\%$ of the consecutive 30 nights (i.e., 21 days) during the first 3 months of treatment initiation. The patients were classified into two groups: compliant and non-compliant. Logistic regression analyses were performed to identify the clinical factors and PSG parameters associated with CPAP compliance.

Results Of the 188 participants, 80 were classified into the compliant group and 108 into the non-compliant group. The ratios of stage N1 ($p=0.011$) and health insurance coverage ($p=0.007$) were significantly associated with compliance with CPAP, with an explanatory power of 18.6% ($R^2=0.186$, $p<0.001$).

Conclusion Stage N1 ratio and health insurance coverage were significant predictors of CPAP compliance. It is necessary to confirm whether the relationship between a high stage N1 ratio and compliance can be reproduced in a larger sample and in individuals from other countries.

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Keywords Compliance; Continuous positive airway pressure; Obstructive sleep apnea; Polysomnography; Predictors.

INTRODUCTION

Obstructive sleep apnea (OSA) is a common sleep disorder

characterized by repeated episodes of obstruction of the upper airway.¹ It can cause sleep disturbance, daytime sleepiness, and an increased risk of cardiovascular problems such as hypertension, ischemic heart disease, and cerebrovascular disease.^{1,2} Treatments for OSA include continuous positive airway pressure (CPAP), oral appliances, and uvulopalatopharyngoplasty, with CPAP being the treatment of choice.^{1,3,4} CPAP is a pneumatic splint that maintains the patency of the upper airway in a dose-dependent manner.³ Previous studies have reported that CPAP can reduce daytime sleepiness, alleviate cardiovascular complications, and improve cognitive function.^{3,5,6}

Although the therapeutic effect of CPAP has been demonstrated, a period of adaptation to CPAP is required because patients with OSA must sleep with a mask on their nose daily and some patients fail to adapt. With compliance defined in previ-

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ous studies as the CPAP device being used for 4 h or more on 70% of days, the subjective compliance was 65%–90%,⁷ and the objective compliance identified through objective monitoring was 40%–83%.^{8,9} According to a study conducted in Korea, the subjective compliance rate was 34% and the objective compliance rate was 20.7%, which was lower than that of other countries because it was conducted before health insurance covered CPAP treatment.¹⁰ Since adherence to CPAP determines the success or failure of OSA treatment, which factors predict adherence before treatment begins, is a clinically interesting topic.

Insomnia, claustrophobia, nasal stiffness, dry mouth and throat, and frequent awakening during CPAP were noted as factors that decreased compliance with CPAP.^{11–14} Conversely, factors associated with increased compliance included old age, female sex, daytime sleepiness (i.e., Epworth Sleepiness Scale [ESS] total score >10), severity of OSA (i.e., apnea hypopnea index [AHI] >30 events per hour), low severity of depression and insomnia, low O₂ saturation, and hypnotics use during CPAP titration.^{10,15–17} Previous studies showed that results varied depending on the study group, including interracial differences (such as finding significant relationships among African Americans), lower socioeconomic status, and poor adherence to CPAP.^{3,18} However, since few studies have been conducted on predicting factors for CPAP compliance in Korea, further studies on this topic and the differences in clinical characteristics and polysomnography (PSG) results between compliant and non-compliant groups are needed.

The aims of this study were 1) to identify the factors predicting compliance with CPAP in patients with OSA and 2) to compare the demographic and clinical characteristics of patients who were compliant or non-compliant with CPAP.

METHODS

Participants

We retrospectively reviewed the medical records, PSG records, and self-report questionnaires of patients with OSA who were treated at the Gil Medical Center between Jan 2014 and Jun 2019. All patients were diagnosed with OSA based on PSG by board-certified otolaryngologists with more than 10 years' clinical experience in OSA and sleep medicine, and treated with CPAP or automatic positive airway pressure (APAP). OSA diagnosis was made based on the diagnostic criteria of the International Classification of Sleep Disorder-3 when AHI ≥ 5 and having related symptoms or AHI ≥ 15 .¹⁹ CPAP (or APAP) was prescribed for patients with AHI ≥ 15 or AHI ≥ 5 and OSA-related symptoms or disease (i.e., excessive daytime sleepiness, nocturnal sleep disturbance hypertension, heart disease, or history of cerebrovascular disease).

The criterion for compliance was the use of CPAP devices for ≥ 4 h per night for $\geq 70\%$ of the consecutive 30 nights (i.e., 21 days) during the first 3 months of treatment initiation. This compliance standard is also the CPAP reimbursement standard of the Korean National Health Insurance System, which has been in effect since July, 2018. The patients were classified into two groups: compliant and non-compliant. If not covered by the national health insurance, the cost of purchasing a CPAP (or APAP) machine was 1,627–2,033 USD; however, if it was covered by the national health insurance, the patient paid approximately 14 USD per month. All OSA patients who had used CPAP after July 2018 were covered by their health insurance for the rent of the positive airway pressure machine.

Self-report questionnaires

All participants completed self-report questionnaires during PSG. The questionnaire comprised questions about demographic information (marital status, education, occupation status, etc.) and medical illnesses (especially hypertension, ischemic heart disease, and cerebrovascular disease), as well as clinical questionnaires regarding sleep and depression.

Participants' sleep quality and insomnia severity were evaluated using the Pittsburgh Sleep Quality Index (PSQI) and the Insomnia Severity Index (ISI).^{20,21} The PSQI is a self-report questionnaire designed to evaluate subjective sleep quality and calculate the total score, sleep efficiency, and total sleep time.²⁰ The ISI is a 7-item scale measuring the severity of insomnia, with higher scores indicating more severe insomnia.²¹ Daytime sleepiness was evaluated using the ESS.²² The severity of depression was total sleep the Beck Depression Inventory (BDI).²³

Polysomnography

All participants underwent in-laboratory nocturnal PSG with standard recordings in accordance with the recommendations of the American Academy of Sleep Medicine (AASM).²⁴ During PSG, weight, height, and neck circumference were measured. The channels monitored during PSG included six electroencephalography leads (F3, F4, C3, C4, O1, and O2), three electromyography channels (chin and both anterior tibialis muscles), two electrooculogram channels (E1–M2 and E2–M2), and one electrocardiography channel. Respiration, chest and abdominal movements, and oxygen desaturation were also monitored. The recorded PSG data were analyzed and interpreted according to the manufacturer's instructions for the COMET systems (Grass-Telefactor Corporation, West Warwick, RI, USA).

The PSG data were scored based on the criteria in the AASM manual.²⁴ The PSG results were confirmed by sleep special-

ists. The AHI, O₂ saturation nadir, total sleep time, sleep efficiency, wake after sleep onset, sleep onset latency, rapid eye movement sleep latency, total arousal index, and sleep stage (N1, N2, N3, and R) were included in the statistical analysis. The loudness of the snoring sounds (no snoring, soft snoring, and loud snoring) evaluated by the sleep technician during PSG was also included in the analysis parameters.

Statistical analysis

The demographic data, clinical scale scores, and PSG results of the two groups were analyzed using independent t-tests for continuous variables and chi-square tests for dichotomous variables. The patients were further categorized into four groups according to compliance and insurance coverage status, and a one-way analysis of variance (ANOVA) was performed. We used Bonferroni's method as a post-hoc test to compare significant inter-group differences in each of the four groups. Logistic regression analyses were performed to identify the clinical factors and PSG parameters associated with compliance with CPAP therapy. The independent variables were important clinical variables (i.e., AHI) that were expected to affect compliance with CPAP and had a significance of $p < 0.1$ as determined using independent t-tests. All statistical analyses were conducted using SPSS (version 23.0, IBM Corp, Armonk, NY, USA) with a cutoff value of $p < 0.05$ (two-tailed).

Ethics statement

Informed consent was waived owing to the observational nature of the study, and the consent waiver was approved by the Institutional Review Board of Gil Medical Center (GAIRB2022-103).

RESULTS

Demographic, clinical, and PSG data

A total of 188 patients were included in this study. The average age was 47.4 years (range, 21–74 years), and most patients were male ($n=172$, 91.5%). Of the 188 participants, 80 (42.6%) were classified into the compliant group and 108 (57.4%) into the non-compliant group. A comparison of the demographic characteristics of the two groups is shown in Table 1. Age ($t=-2.10$, $p=0.038$) was higher in the compliant group, but there was no significant sex difference. Additionally, there were no differences between the two groups in terms of marital status, educational level, or occupational status. Hypertension ($\chi^2=5.02$, $p=0.025$) and medical insurance coverage ($\chi^2=7.29$, $p=0.007$) were significantly higher in the compliant group than in the non-compliant group. Of these participants, 109 (58.0%) received APAP. The proportion of APAP users in the compliant and non-compliant groups was 60.0% and 56.5%, respectively, with no significant differences between the two groups ($\chi^2=0.23$, $p=0.629$). The mean CPAP pressure in the compliant and non-compliant groups was 8.6 and 8.9 cm H₂O, respectively, with no significant difference between the two groups ($t=-1.21$, $p=0.227$).

Table 2 shows the differences in sleep and depression clinical questionnaires between the two groups. There was no significant difference in the total ESS or BDI total scores between the two groups. Although there was no significant difference between the two groups on the ISI scale, the p values of the ISI total score ($t=1.67$, $p=0.097$), and items “dissatisfaction with sleep” ($t=1.69$, $p=0.094$) and “how noticeable to other people” ($t=1.81$, $p=0.072$) were <0.1 ; therefore, these variables

Table 1. Demographic and clinical characteristics of compliant and non-compliant with CPAP therapy

Variables	Total participants (N=188)	Compliant (N=80)	Non-compliant (N=108)	Statistics [†]
Age (yr)	47.4±11.2	49.4±10.9	46.0±11.2	$t=-2.10$, $p=0.038^*$
Sex, male	172 (91.5)	74 (92.5)	98 (90.7)	$\chi^2=0.18$, $p=0.669$
Married [‡] (N=174)	134 (77.0)	57 (76.0)	77 (77.8)	$\chi^2=2.67$, $p=0.445$
Education (yr)	14.1±2.4	14.0±2.5	14.2±2.3	$t=0.77$, $p=0.445$
Job [§] (N=174)	146 (83.9)	60 (80.0)	86 (86.9)	$\chi^2=1.49$, $p=0.222$
Hypertension (N=174)	67 (35.6)	36 (48.0)	31 (31.3)	$\chi^2=5.02$, $p=0.025^*$
Body mass index	27.8±4.5	27.8±4.3	27.8±4.6	$t=-0.01$, $p=0.995$
Neck circumference	40.1±3.4	40.1±3.6	40.0±3.3	$t=-0.19$, $p=0.849$
Systolic BP	134.8±16.7	134.1±17.4	135.3±16.2	$t=0.49$, $p=0.623$
Diastolic BP	88.7±47.8	92.4±71.2	85.8±14.1	$t=-0.93$, $p=0.355$
Covered by health insurance	96 (51.1)	50 (62.5)	46 (42.6)	$\chi^2=7.29$, $p=0.007^{**}$
APAP users	109 (58.0)	48 (60.0)	61 (56.5)	$\chi^2=0.23$, $p=0.629$

Data are mean±standard deviation or N (%) values. * $p < 0.05$; ** $p < 0.01$; [†]independent t-test or chi-square test; [‡]married and currently has a spouse; [§]number of participants with jobs. BP, blood pressure; CPAP, continuous positive airway pressure; APAP, automatic positive airway pressure

were included as independent variables in the regression equation. There was no significant difference in the PSQI total score between the two groups; however, the compliant group showed lower scores on the “overall sleep quality” question, indicating better sleep quality ($t=2.41$, $p=0.017$).

Among the PSG variables, only the stage N1 ratio showed a significant difference between the two groups, with the compliant group showing a higher N1 percentage ($t=-2.06$, $p=0.041$). There were no significant ($p<0.1$) variables among the other PSG parameters. Detailed data are presented in Table 3.

Table 2. Comparison of self-report questionnaires between compliant and non-compliant with CPAP groups

Questionnaire	Compliant (N=80)	Non-compliant (N=108)	Statistics†
ESS, total score	8.6±3.7	8.3±3.6	$t=-0.49$, $p=0.625$
BDI, total score	10.5±7.0	11.1±7.8	$t=0.60$, $p=0.551$
Insomnia severity index			
Total score	14.2±5.6	15.6±5.7	$t=1.67$, $p=0.097^*$
Difficulty falling asleep	0.6±0.8	0.7±1.0	$t=0.89$, $p=0.374$
Difficulty staying asleep	0.9±1.1	1.1±1.1	$t=1.24$, $p=0.218$
Waking up early	1.3±1.1	1.5±1.2	$t=0.91$, $p=0.364$
How dissatisfied	3.3±1.2	3.6±1.0	$t=1.69$, $p=0.094^*$
How noticeable	2.3±1.2	2.7±1.2	$t=1.81$, $p=0.072^*$
How worried/distressed	3.0±1.3	3.2±1.3	$t=0.57$, $p=0.567$
Interfering with function	2.7±1.1	2.9±1.1	$t=1.22$, $p=0.223$
PSQI			
PSQI, total score	7.8±2.9	8.2±3.4	$t=0.52$, $p=0.603$
PSQI, total sleep time	380.3±75.3	384.6±79.2	$t=0.37$, $p=0.715$
PSQI, sleep efficiency	90.5±11.6	91.1±12.5	$t=0.32$, $p=0.752$
Overall sleep quality	1.7±0.8	2.0±0.7	$t=2.41$, $p=0.017^{**}$

Data are mean±standard deviation values. * $p<0.1$; ** $p<0.05$; †independent t-test. BDI, Beck Depression Inventory; CPAP, continuous positive airway pressure; ESS, Epworth Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index

Table 3. Comparison of the polysomnographic data between the compliant and non-compliant with CPAP groups

Variables	Compliant (N=80)	Non-compliant (N=108)	Statistics†
Apnea hypopnea index	45.2±23.6	47.0±24.5	$t=0.53$, $p=0.597$
O ₂ saturation nadir	74.9±13.0	76.8±10.6	$t=1.11$, $p=0.267$
CPAP pressure, cm H ₂ O	8.6±1.5	8.9±1.8	$t=-1.21$, $p=0.227$
Total sleep time (min.)	339.4±338.8	338.8±58.1	$t=-0.07$, $p=0.946$
Sleep efficiency (%)	82.8±11.8	83.0±11.9	$t=0.15$, $p=0.884$
Wake after sleep onset (%)	15.4±11.5	14.5±11.0	$t=-0.55$, $p=0.585$
Sleep onset latency	8.9±9.8	11.1±19.9	$t=0.88$, $p=0.380$
REM sleep latency	138.5±89.6	146.6±86.2	$t=0.62$, $p=0.533$
PLMS (N/h)	3.2±8.5	3.4±10.8	$t=0.11$, $p=0.915$
Total Arousal Index (N/h)	41.4±20.7	38.6±21.9	$t=-0.89$, $p=0.375$
Loudness of snoring sound‡	1.8±0.5	1.9±0.5	$t=1.61$, $p=0.109$
Sleep architecture			
Stage N1 (%)	31.2±16.3	26.6±14.5	$t=-2.06$, $p=0.041^*$
Stage N2 (%)	46.9±16.1	45.2±114.9	$t=-0.75$, $p=0.455$
Stage N3 (%)	3.0±7.0	2.1±3.6	$t=-1.11$, $p=0.268$
Stage R (%)	13.0±6.2	13.1±6.5	$t=0.12$, $p=0.907$

Data are mean±standard deviation values. * $p<0.05$; †independent t-test; ‡loudness of the snoring sound during polysomnography: 0, no snoring; 1, soft snoring; 2, loud snoring. CPAP, continuous positive airway pressure; N/h, number per hour; PLMS, periodic limb movements during sleep; REM, rapid eye movement

Table 4. Logistic regression predicting CPAP compliance

Variables	B	SE	Wald chi-square	p	Odds ratio	95% CI
Constant	1.34	0.771	3.034	0.082		
Apnea hypopnea index [†]	-0.02	0.009	3.494	0.062	0.984	0.967–1.001
Hypertension	0.66	0.358	3.433	0.064	1.94	0.962–3.916
Stage N1 (%)	0.04	0.014	6.516	0.011*	1.037	1.008–1.067
PSQI, overall sleep quality	-0.42	0.238	3.152	0.076	0.655	0.411–1.045
Covered by health insurance	-0.97	0.359	7.291	0.007**	0.379	0.188–0.767
Significance of the regression model				<0.001***		

Nagelkerke $R^2=0.186$ (the regression equation can explain the phenomenon by 18.6%). The final model predicted the actual data with a predictive value of 64.2%. Logistic regression analysis for compliance with independent variables such as age, hypertension, health insurance coverage, ISI (total score, dissatisfaction with sleep, how noticeable), overall sleep quality in the PSQI, and ratio of stage N1. * $p<0.05$; ** $p<0.01$; *** $p<0.001$; [†]entered as independent variables because of their clinical importance. CPAP, continuous positive airway pressure; CI, confidence interval; PSQI, Pittsburgh Sleep Quality Inventory; SE, standard error; ISI, insomnia severity index

In the four groups categorized according to compliance and insurance coverage status, One-way ANOVA revealed significant differences at stages N1 ($F=3.678$, $p=0.013$) and N3 ($F=2.695$, $p=0.047$) (Supplementary Tables 1 and 2 in the online-only Data Supplement). Individual post hoc comparisons of the two groups revealed a significant difference in stage N1 percentage between the non-compliant and insured group and the compliant but uninsured group ($p=0.009$).

Predicting factors that affected compliance with CPAP

Logistic regression analysis using the likelihood ratio method was performed for compliance. Independent variables in the regression analysis included age, AHI, hypertension, health insurance coverage, ISI (total score, dissatisfaction with sleep, and how noticeable it was), PSQI overall sleep quality, and ratio of stage N1. The results are presented in Table 4. The ratios of stage N1 ($B=0.04$, $p=0.011$) and health insurance coverage ($B=-0.97$, $p=0.007$) were significantly associated with compliance with CPAP, with an explanatory power of 18.6% ($R^2=0.186$). The significance of this regression model was $p<0.001$ and the predictive value was 64.2%.

DISCUSSION

This study evaluated and compared the demographic, clinical, and PSG variables of patients with and without CPAP compliance and investigated the predictive factors associated with CPAP compliance. The results indicated that the compliant group was older and had a higher frequency of hypertension, a higher frequency of health insurance coverage, better sleep quality on the PSQI, and a higher ratio of stage N1 on PSG. In the regression analysis, stage N1 ratio and health insurance coverage were significant factors that predicted compliance with CPAP therapy.

In this study, the average age was higher, and the frequency of hypertension was higher in the CPAP-compliant group. The average age of the participants in this study was 47.4 years old, middle-aged. It is possible that older individuals are more aware of their OSA symptoms and worried about OSA complications, which may be related to CPAP compliance. Previous studies reported inconsistent results regarding the association between compliance and age. For instance, in previous studies in the United States and Italy, the compliant group was older,^{17,25} and in a Korean study, the CPAP compliance rate increased as the age increased.¹⁶ However, a Singapore study showed that there were more older age groups among those who did not start treatment at 1 month.²⁶ The age of participants in that study ranged from 14 to 89 years old, and the super-aged patients might have felt burdened to start a new CPAP treatment.²⁶ Conversely, there were studies that showed no age difference between the compliant and non-compliant groups.²⁷⁻²⁹ In our study, the proportion of patients with hypertension was high in the compliant group. Individuals with high blood pressure are more diligent in using CPAP because they feel the need for OSA treatment. However, previous studies have shown inconsistent findings on the relationship between hypertension and CPAP compliance. While there was a study in which the history of hypertension was higher in the CPAP-compliant group,³⁰ there were studies in which hypertension was not associated with CPAP adherence,³¹⁻³³ and other studies showed an increased risk of non-adherence to CPAP in patients with hypertension.³⁴

Among the clinical scales, only the overall sleep quality item on the PSQI showed a significant difference between the compliant and non-compliant groups.¹⁰ By contrast, the effect of insomnia severity on CPAP compliance has been previously reported. A German study showed that the Regensburg Insomnia Scale predicted 6-month CPAP compliance.¹² A study on US Hispanic veterans found that insomnia was associated

with poor adherence to CPAP,³⁵ and a French study showed that sleep initiation and maintenance disorder were associated with long-term compliance of CPAP.¹⁴ In this study, the difference between the two groups on the ISI total score, and the ISI dissatisfaction and noticeability items, which are measures of insomnia severity, had *p* values <0.1. Therefore, they were included in the regression equation as potential variables to predict compliance but were ultimately not found to be significant predictors. Additionally, some studies have demonstrated a significant association between ESS scores and CPAP compliance,^{9,26} although there was no significant difference in ESS scores between the two groups in this study.

The factors that were significantly associated with CPAP compliance in the logistic regression were stage N1 ratio and health insurance coverage. Although not statistically significant, AHI, hypertension, and PSQI overall sleep quality were included in the regression equation. The results of the PSG stage N1 ratio predicting CPAP compliance are novel and have not been previously reported. In a previous study, all sleep stage variables, including the stage 1 sleep ratio, from nocturnal diagnostic PSG and CPAP titration tests did not predict CPAP compliance.³⁶ The high stage N1 ratio predicting high CPAP adherence in this study might be the result of patients with OSA and poor objective sleep quality, recognizing their poor sleep quality and therefore using CPAP consistently. Consistent with this study, previous studies have shown that factors such as sleep architecture, sleep efficiency, and sleep latency are associated with CPAP compliance.³⁷ If this result is replicated in larger samples in the future, it will be possible to predict CPAP adherence based on PSG results and to provide personalized education and treatment directions to patients. A high proportion of people receiving health insurance coverage in the CPAP-compliant group was an expected result, and the coverage action for CPAP in the Korean National Health Insurance System can be evaluated to make a significant contribution to increasing OSA patient compliance.

A wide range of factors have been reported to predict CPAP compliance in patients with OSA, including demographic variables (sex^{38,39} and age¹⁵), clinical factors (OSA severity, comorbidities, sleep dissatisfaction,⁴⁰ and nocturnal insomnia^{40,41}), CPAP device, and treatment-related factors (device comfort, mask type,⁴² pressure settings,⁴³ and duration of use⁴³). However, the results of the studies reporting these factors were inconsistent. The discrepancies in these results included variations in study design, population characteristics, measurement methods, geographical and cultural influences, publication bias, confounding variables, sample size, patient heterogeneity, technological advancements in CPAP machines and masks, and differences in CPAP education.

In this study, the significant variable predicting compliance

to CPAP therapy was the ratio of stage N1 disease at baseline PSG to health insurance coverage. As this study was conducted on a Korean population under the Korean National Health Insurance System, further studies including different ethnicities and socioeconomic statuses should be conducted to generalize the findings to other countries.^{44,45} Moreover, it is necessary to confirm whether the effect of a high stage N1 ratio on compliance is reproduced in a larger sample study and in individuals from other countries. If replicated, this could be considered a useful clinical predictor in the future. A comprehensive review and analysis of these predictors can provide valuable insights into enhancing CPAP compliance with CPAP and improving OSA management.

Supplementary Materials

The online-only Data Supplement is available with this article at <https://doi.org/10.30773/pi.2023.0175>.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

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