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Seasonal effects on the continuous positive airway pressure adherence of patients with obstructive sleep apnea

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Authors' statement

We confirm that all authors have made significant contributions to this manuscript. They have seen and approved the final manuscript and agreed to its submission to *Sleep Medicine*.

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ABSTRACT

Objective: This study examined seasonal differences in continuous positive airway pressure (CPAP) therapy adherence among patients with obstructive sleep apnea (OSA).

Methods: Patients aged ≥ 20 years with OSA who had used CPAP devices on the automatic setting for >12 consecutive months (n = 141) were included in this retrospective study from December 2015–2016. The information of CPAP use (pressure, hours of actual use) was extracted from database downloaded from patients' CPAP devices. Patients were divided into adherent and non-adherent groups using the cutoff point of 70% CPAP use for ≥4 h daily over the 1-year study period. CPAP use data were averaged for each season.

Results: Patients in the adherent group were significantly older than those in the non-adherent group ($p < 0.001$). In the adherent group, the rate of ≥4 h daily CPAP use was significantly lower, the daily duration of CPAP use was significantly shorter, and the residual apnea–hypopnea index (AHI; events/hour) was significantly higher in summer than in other seasons (all $p < 0.001$). In the non-adherent group, the duration of daily CPAP use and the AHI differed significantly between winter and summer ($p = 0.008$ and $p < 0.001$, respectively).

Conclusions: Seasonal changes were associated with the CPAP adherence of patients with OSA. The study findings suggest that there is possibility of increasing the duration of CPAP use by adjusting the bedroom environment in hot and humid seasons.

Keywords:

Obstructive sleep apnea, Continuous positive airway pressure, Adherence, Seasonal change

1. Introduction

Continuous positive airway pressure (CPAP) is the first-line treatment for obstructive sleep apnea (OSA), and is associated with the prevention of hypertension [1], improvement of quality of life [2], and longevity [3], but it may not have the expected effects when patients' adherence at home is inadequate. Thus, the creation of an environment facilitating patients' home CPAP use is important to increase treatment effectiveness.

The Japanese health insurance system mandates that patients who use CPAP devices visit clinics or hospitals every 1–3 months to address concerns arising from individual CPAP usage data, receive educational interventions, resolve CPAP-related problems (e.g., dry nose/mouth, air leakage from the mouth, device noise), and have the fit of their masks and headgear adjusted. These opportunities to resolve issues promptly facilitate CPAP adherence. In winter, however, patients with OSA and nasal symptoms show reduced CPAP adherence due to the cold air emitted by the device; in spring, CPAP adherence worsens among these patients due to pollen allergies. Cassol et al. [4] reported reduced laboratory-measured apnea–hypopnea index (AHI) scores in winter relative to other seasons in Brazil. Seasonal changes in the AHI are also observed in clinical practice in Japan. Seasonal variations may also impact the bedroom environments of CPAP users with OSA. Thus, this study was conducted to examine seasonal changes in the CPAP adherence of patients with OSA and to identify seasonal factors influencing CPAP adherence among these patients in Japan.

2. Methods

2.1. Design, setting, and participants

This retrospective study was conducted at the Center for Sleep Medicine of the Ehime University Hospital, Ehime, Japan (43°N, 141°E), which is located in a suburban region. A single-center design was selected to ensure data quality and avoid confounding factors. The lowest and highest average ambient temperatures in the area during the study period were −0.6°C (February) and 37.2°C (August), respectively. The lowest and highest average ambient relative humidity values were 61% (February, March, May, and December) and 77% (October), respectively. The mean concentrations of sulfur dioxide, suspended particulate matter, nitrogen dioxide, and carbon monoxide during the study period met Japan's 2015 environmental standards [5], and air pollution was not a problem in the area.

From a total of 254 patients on CPAP treatment in November and December 2016, 141 patients with OSA were included in this study. Additional eligibility criteria were: 1) age ≥ 20 years, 2) >12 consecutive months of center visitation for CPAP treatment, 3) ability to respond to questionnaires, and 4) use of REMstar Auto System One CPAP devices (Philips Respironics, Inc., Murrysville, PA, USA) with the automatic setting. Participating patients were followed by the center's neurologist, cardiologist, and otolaryngologist. Nurses provided patient education and support and served as sleep technologists. The data extracted from CPAP device from November 2015- October 2016 were averaged and analyzed as participant's adherence for each season. Personal information including age (years), gender (man/woman) and body mass index (BMI) were obtained by electronic medical record.

The institutional review board of Ehime University Hospital (no. 1609021) and the ethics committee of Kyoto University Graduate School of Medicine (no. R0796) approved this study. Written informed consent was obtained from all participating patients.

2.2. Subjective sleepiness and diagnostic assessments

Daytime sleepiness before the initiation of CPAP use was assessed at patients' first visits to the outpatient clinic using the Japanese version of the Epworth Sleepiness Scale (JESS) [6], a self-administered, self-reported eight-item questionnaire. Possible item scores range from 0 and 3 and possible total (summed) scores range from 0 to 24; total scores ≥ 11 are taken to suggest excessive daytime sleepiness (EDS). The validity of the JESS has been confirmed.

Patients underwent full diagnostic polysomnographic (PSG) assessment before the initiation of CPAP therapy. This assessment was performed under technician-attended conditions and using standard parameters in our center's laboratory. Six electroencephalogram channels (F4-M1, F3-M2, C4-M1, C3-M2, O2-M1, and O1-M2) with right and left electrooculograms, a chin electromyogram, pulse oximetry, an oronasal thermistor, and a nasal air pressure transducer were employed. Snoring was audio-recorded, thoracic and abdominal respiratory efforts were indexed using respiratory inductance plethysmography, electrocardiography and anterior tibialis electromyography were used, and body position was recorded. OSA severity was estimated using the American Academy of Sleep Medicine criteria [7].

2.3. CPAP questionnaire administration

At the time of study enrollment, patients filled out an original questionnaire for this study that solicited data on patients‘ characteristics including job type, marital status and information on seasonal nasal symptoms (i.e. allergies) and difficulty with CPAP use due to nasal symptoms, tube or mask discomfort, and their bedroom environments (e.g., air conditioning, disturbing noises due to air leakage from the CPAP device or from outdoors or bedpartners) in the previous 12 months from 2015 to 2016. Responses had a “yes/no” format on 12 items. We defined spring as March–May, summer as June–August, autumn as September–November, and winter as December–February according to the standards of the Japan Meteorological Agency [8]. Questionnaire responses were coded as “yes” for a given season when a patient provided at least one "yes" response to an item for that season.

2.4. Assessment of CPAP use and adherence

We extracted data on daily CPAP use (in minutes and as a percentage), CPAP use for ≥4 h daily (percentage), the residual AHI (events/hour), mean overnight pressure (in cmH_2O), pressure occupying the 90th percentile of the total overnight pressure (≥90% pressure; cmH_2O), and use of heated humidifier/tube (on/off) in the previous 12 months from patients' CPAP devices prior to questionnaire administration. These data were averaged for each season.

For CPAP adherence, we used the cutoff of 70% CPAP use for ≥4 h daily; although numerous clinical definitions of CPAP adherence exist, this threshold is widely accepted [9]. Patients were divided into adherent and non-adherent groups based on 12 months of CPAP data using this threshold.

2.5. Statistical analysis

Continuous data were expressed as means and standard deviations (SDs), and categorical data were reported as proportions. The study data were compared among seasons. Categorical data were analyzed using the chi-squared test. For normally and non-normally distributed data, differences between means were assessed using Student's *t* test and the Mann–Whitney *U* test, respectively. CPAP data were compared using repeated-measures analysis of variance with the post-hoc Tukey's test. Fisher's exact test was used to compare demographic and CPAP adherence data. Variables were also compared between the adherent and non-adherent groups. A simultaneous multivariable logistic regression model (Firth's logistic regression) was used to estimate adjusted odds ratio (OR) and a 95% confidence interval (CI) for the associations between seasonal factors and CPAP adherence. Correlations among the BMI, AHI, and JESS scores were assessed separately in men and women using Spearman's correlation analysis. For all tests, p values < 0.05 was considered to be significant. The statistical analyses were performed using the SAS 9.4 software (SAS Institute Inc., Cary, NC, USA).

3. Results

Patient characteristics are presented in Table 1. Ninety (63.8%) patients were aged > 65 years, in 62.8% of men and 66.7% of women, respectively. Nearly half (43.3%) of the patients were unemployed or retired. Most patients were living with partners or family members, and 97.2% of them had sleeping partners. The most frequently recorded conditions in patients' medical histories were hypertension (31.9%), diabetes (19.9%), and arrhythmia

(11.3%); 67 (47.5%) patients had no relevant medical history.

The mean BMI was 25.5 ± 4.5 kg/m^2 and did not differ significantly between men and women (25.5 ± 4.2 and 25.5 ± 5.2 kg/m^2, respectively). The mean AHI was 41.9 ± 15.5 events/h and was significantly higher among men than among women (43.7 ± 16.4 vs. 37.4 ± 11.9 events/h; p = 0.014). Most (78.0%) patients had severe OSA (AHI ≥ 30 events/h). The BMI and AHI correlated significantly in men and women (r = 0.29, p = 0.003 and r = 0.51, p = 0.001, respectively). The mean JESS score was 9.4 ± 4.9, and was significantly higher among men than among women (10.0 ± 4.9 vs. 7.8 ± 5.1; p = 0.019). According to JESS scores, 41 (36.9%) patients had EDS.

More than half of the patients had been using CPAP devices for >4 years. The average daily CPAP use in all seasons exceeded 85%; the use rate varied significantly among seasons, with the lowest rate reported for spring and the highest reported for autumn (Table 2). CPAP use ≥4 h daily and daily CPAP use (in minutes) were significantly lower, and the residual AHI was significantly higher, in summer than in other seasons.

Patients in the adherent group were significantly older than those in the non-adherent group; all other clinical characteristics were similar in the two groups (Table 3). The period of CPAP use did not differ significantly between the adherent and non-adherent groups (3.6 ± 1.3 vs. 3.1 ± 1.4 years, respectively; p =0.052). No significant difference in the percentage of patients with EDS was observed between groups (n = 32, 68.1% vs. n = 15, 31.9%; p = 0.388). More than half of patients in the adherent and non-adherent groups (64.0% and 71.2%, respectively) had not experienced EDS before the initiation of CPAP treatment.

Seasonal CPAP data for the adherent and non-adherent groups are provided in Table 4. CPAP use for ≥4 h daily, daily CPAP use (in minutes), and the residual AHI differed significantly among seasons in both groups. In the adherent group, CPAP use for ≥4 h daily and daily CPAP use (in minutes) were lower, and the residual AHI was higher, in the summer than in other seasons. In the non-adherent group, the percentages of daily CPAP use and CPAP use for ≥4 h daily were greater in spring than in other seasons, but the residual AHI was not smallest in spring. The daily duration of CPAP use was shortest in summer and longest in winter (263 ± 68 vs. 286 ± 78 min, p = 0.008), and the residual AHI was highest in summer and lowest in winter (3.8 ± 3.1 vs. 3.0 ± 2.4 events/h, p < 0.001).

The electric fan use in autumn were related significantly to seasonal CPAP adherence (OR; 0.29, 95% CI 0.11–0.73) (Table 5). Additionally, the presence of complain due to the condensation of CPAP (OR; 7.81, 95% CI 1.48–41.14) and CPAP condensation in winter was also a significant factor (OR; 2.74, 95% CI 1.02–7.35) in adherent group compared with non-adherent group in autumn and in winter. In contrast, trouble with CPAP use due to condensation was significantly associated with less CPAP adherence (OR; 0.17, 95% CI

0.03–0.97). However, the rate of the condensation of CPAP was not significant in the adherent group than in the non-adherent group (in autumn; 19.4% and 8.3%, in winter; 59.4% and 48.9%, respectively). The rate of the trouble of CPAP use related to the condensation was not significant between adherent and non-adherent groups (7.5% and 10.4%, respectively). The proportion of patients with nasal allergies in spring was greatest in the adherent group than in the non- adherent group (32.6% vs. 45.7%) with no significant difference between groups. Trouble with CPAP use due to nasal allergies was reported least in autumn in the adherent and non-adherent groups (8.6% and 8.3%, respectively) with no significant difference between groups. The maximum proportion of patients who had difficulties with CPAP use due to nasal allergies was 20.3% during summer in the non-adherent group; the proportion of difficulties in the same group in winter was 22.2%. The rate of electric fan use in autumn was significantly lower in the non-adherent group than in the adherent group (45.8% and 21.5%, respectively; $p = 0.003$). No significant difference between groups was observed for other bedroom environment- and device-related factors.

4. Discussion

The present study demonstrated that CPAP adherence among patients with OSA in Japan differs seasonally. It tended to be worse in summer, when AHIs were worst, than in other seasons. The percentage of CPAP use for ≥4 h daily and the duration of daily CPAP use were worst in non-adherent group in summer. However, the seasonal change in the percentage of daily CPAP use differed from the seasonal variation in AHI. The rate of CPAP use for ≥4 h daily differed between the adherent and non-adherent groups by about 40%, and the duration of daily CPAP use differed by about 100 min, in all seasons. In the adherent group, the rate of daily CPAP use exceeded 95% throughout the year, which may have obscured the effects of seasonal fluctuations on CPAP treatment effectiveness. Even in the adherent group, however, in which the rate of daily CPAP use for ≥4 h daily approached 90%, the duration of daily CPAP use showed significant seasonal variation. Seasonal differences in the rates of daily CPAP use and CPAP use for ≥4 h daily did not match the variation in the AHI, but the duration of CPAP use did. These results show that the duration (rather than rate) of daily CPAP use is an important indicator of seasonal effects, and suggest that the provision of patient support to increase this duration could improve the effectiveness of CPAP treatment more efficiently than could an increase in the number of days with ≥4 h CPAP use. Certainly, the cutoff of 70% CPAP use for ≥4 h daily is ultimately important, but if the patient is not adherent for CPAP treatment, the duration of daily CPAP use cannot be ignored.

The significance of the ≥4 h daily CPAP use rate has been demonstrated with the observation of dose–response effects of the duration of nightly CPAP use on clinical outcomes [10–12]. The percentage of ≥4 h daily CPAP use has also been associated with lower AHIs [12,13]. Accordingly, our results not only indicate the existence of seasonal variations in CPAP adherence, but also suggest that the rate of ≥4 h daily CPAP use is related to more effective improvement of CPAP treatment outcomes, especially in hotter seasons.

OSA severity did not differ between the adherent and non-adherent groups in this study, but age did. Previous evidence suggests the existence of a relationship between OSA severity and CPAP adherence, given observed correlations with age, race, the BMI, insomnia severity, and self-efficacy [14,15]. Leppänen at el. [16] reported that the AHI increased with age. Several issues with CPAP use, such as social background and lifestyle factors, may depend on age. Bed partners [17,18] and ESS score [19] have also been associated with CPAP adherence, although no such association was observed in this study, possibly due to differences in the bedroom environments and cultural backgrounds of patients participating in relevant studies.

In a cosinor analysis of PSG data from 7,523 patients with sleep disorders within 10 years, Cassol et al. [4] found that the AHI differed significantly among seasons (being highest in winter), independent of patient sex, age, BMI, neck circumference, and relative air humidity. Brander et al. [20] reported that nasopharyngeal symptoms such as dryness (74%), sneezing (53%), mucus (51%), nasal obstruction (45%), and rhinorrhea (37%) were common in patients with OSA before the initiation of CPAP treatment; after treatment initiation, sneezing (75%) and rhinorrhea (57%) were worse among these patients in winter than in summer. These findings suggest that OSA severity is associated with seasonal changes, and the AHI is expected to be higher in winter. Allergic symptoms such as asthma, upper airway inflammation, nasal congestion, sneezing, rhinorrhea, and nasal pruritus contribute to the worsening of OSA [21,22]. Similarly, side effects affecting CPAP adherence include upper airway issues (e.g., dry nose, mouth, and/or throat; nasal obstruction; nasal discharge), mask leakage, cold air, and disturbing noises [23,24]. Thus, considering the seasonal variation in upper airway symptoms and OSA severity, CPAP adherence could worsen in spring and winter. However, adherence was worst in summer in this study. Researchers have suggested that a summertime increase in the residual respiratory disturbance index due to air pollution (i.e., elevated particle pollution) directly influences upper-airway inflammatory responses, with increases in upper-airway resistance and collapsibility [25,26]. However, this factor is not applicable to the present study, which was conducted in a region with no air pollution problem.

Several common problems related to springtime and wintertime factors have been resolved through the development and improvement of CPAP devices and the increased prevalence of humidification and heated breathing tubes. Massie et al. [27] found a significant increase in adherence after 3 weeks of CPAP treatment with heated humidification compared with CPAP alone. The routine use of built-in humidification has been shown to reduce nasopharyngeal side effects of CPAP [28,29]. In this study, humidification was not associated significantly with CPAP seasonal adherence. More than half of the patients used CPAP devices with humidification, and the rate of discomfort symptoms related to condensation during CPAP use was low. The proportion of patients reporting nasal issues during CPAP use was smaller in this study than in previous studies [20,30]. Moreover, patients in this study were encouraged proactively to use built-in humidification and heated breathing tubes at the time of CPAP initiation and when they complained of upper-airway dryness during regular clinic visits. Consequently, they did not report issues with CPAP use due to condensation in winter. In general, CPAP use in winter may be considered to be difficult; however, we observed fewer problems during winter than in any other season in this study. In Japan, the use of CPAP devices with humidification and heated breathing tubes, and the widespread distribution of well-insulated homes, may reduce CPAP-related oral and nasal dryness and condensation. According to the Köppen–Geiger classification [31], the climate of Ehime Prefecture is warm and temperate, fully humid, with hot summers. This high humidity may alleviate the wintertime problem of upper-airway dryness among CPAP users. All of these reasons may explain the lack of CPAP-related problems during winter in this study. The patients in the adherent group were more aware of the presence of condensation, but it was the patients in the non-adherent group that had tube and mask condensation affecting CPAP use. However, we may have to interpret this finding cautiously given the extremely wide confidential interval in CPAP use. One of the possible explanations is that the patients in the adherent group adjusted for the presence of condensation and were not affected for CPAP use. The rates of daily CPAP use and electric fan use were significantly lower in the non-adherent group than in the adherent group in autumn. These findings suggest the existence of bedroom environment–related problems during cool and hot seasons, particularly in the non-adherent group. Nilius et al. showed that more condensation is formed in the breathing tube during CPAP use in cool sleeping environment [32]. In addition, condensation in the breathing tube was shown to cause the reduction of effective pressure for CPAP treatment [33]. Difficulty with bedroom CPAP device use in dry and cold season in particular might have been ameliorated by machine technologies such as humidification and heated breathing tube, but bedroom environment might not be adequate to use CPAP. Thus, strategies targeting the bedroom environment may improve the effect of seasons on CPAP adherence.

This study has several limitations. First, it was conducted in a single area of Japan and may have been affected by selection bias. In addition, although the climate in the study area is average for Japan, results from areas with different altitudes and/or house structures, even within Japan, may differ. Second, the design of the study prevented the assessment of causality. Moreover, the accuracy of CPAP questionnaire responses depends on patients' recall. We inquired only about nasal seasonal allergy symptoms, such as rhinitis and hay fever, and did not investigate the effects of other nasopharyngeal symptoms. Finally, we collected data on discomfort and bedroom environment factors related to CPAP use using a self-reported sensory scale. Future studies should examine objective indicators (e.g., temperature and humidity in the bedrooms of large numbers of patients living in different climatic regions) and identify endpoint effect sizes and statistical power. In addition, the factors associated with CPAP adherence in summer need to be explored further.

5. Conclusions

This investigation of associations between seasonal changes and CPAP adherence in patients with OSA showed that CPAP adherence and treatment effectiveness were worse in summer than in other seasons. Our findings can guide the delivery of targeted interventions in appropriate seasons to improve CPAP adherence, and possibly the cost effectiveness of care.

Abbreviations

AHI	apnea–hypopnea index
BMI	body mass index
CI	confidence interval
CPAP	continuous positive airway pressure
EDS	excessive daytime sleepiness
JESS	Japanese version of the Epworth Sleepiness Scale
OR	odds ratio
OSA	obstructive sleep apnea
PSG	polysomnographic

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Table 1

Patient characteristics.

Characteristic	***Total % (n)* or mean ± SD**	***p***
Sex		
Men	72.3 (102)	
Women	27.7 (39)	
Age (years)	66.3 ± 11.1	
Male	66.0 ± 11.8	0.615
Female	67.1 ± 9.5	
Age class (years)		
<50	7.1 (10)	
50–54	9.9 (14)	
55–59	7.8 (11)	
60–64	11.4 (16)	
65–69	21.2 (30)	
70–74	19.2 (27)	
≥75	23.4 (33)	
BMI (kg/m²)	25.5 ± 4.5	
Men	25.5 ± 4.2	0.950
Women	25.5± 5.2	
AHI (events/h)	41.9 ± 15.5	
Men	43.7 ± 16.4	0.014*
Women	37.4 ± 11.9	
AHI class		
5≤ AHI <15/h	1.4 (2)	
15≤ AHI <30/h	20.6 (29)	
AHI ≥30/h	78.0 (110)	

JESS score	9.4 ± 4.9	
Men	10.0 ± 4.9	0.019*
Women	7.8 ± 5.1	
CPAP use period (years)	3.4 ± 1.4	
CPAP use period (years) class)		
1 to <2	14.2 (20)	
2 to <3	13.5 (19)	
3 to <4	17.0 (24)	
4 to <5	29.8 (42)	
≥5	25.5 (36)	
Medical history		
Hypertension	31.9 (45)	
Diabetes	19.9 (28)	
Arrhythmia	11.3 (16)	
Heart disease	9.9 (14)	
Cerebrovascular disease	5.7 (8)	
Employment		
Unemployed/retired	43.3 (61)	
Dependent worker	26.9 (38)	
Independent worker	17.7 (25)	
Homemaker	12.1 (17)	
Marital status		
Married/living together	79.4 (112)	
Single/living alone	20.6 (29)	

AHI values were derived from polysomnographic analysis performed before the initiation of CPAP therapy. $^{*}p < 0.05$, Student's *t* test.

SD = standard deviation; BMI = body mass index; AHI = apnea–hypopnea index; JESS = Japanese version of the Epworth Sleepiness Scale; CPAP, continuous positive airway pressure.

Table 2

CPAP use by season.

CPAP parameter	**All seasons (ref)**	**Spring**[*]	**Summer**[⁑]	**Autumn**[†]	**Winter**[‡]	***Overall p***
Daily use (%)	87.3± 18.6	88.9± 18.1[⁑†]	86.4± 20.4[*]	85.9± 21.0[*]	87.2± 18.6	0.010
Use for ≥4 h/day (%)	73.4± 26.3	75.6± 25.6[⁑]	70.1± 28.2[*†‡]	73.5± 27.7[⁑]	75.3± 26.8[⁑]	<0.001
Daily use (min)	340± 81	344± 82[⁑‡]	329± 81[*†‡]	347± 86[⁑]	356± 86[*⁑†]	<0.001
Residual AHI (events/h)	3.1± 2.4	3.1± 2.8[⁑]	3.5± 2.6[*†‡]	3.1± 2.3[⁑]	2.9± 2.1[⁑]	<0.001
Mean pressure (cmH_2O)	6.2± 1.3	6.1± 1.3	6.2± 1.3	6.2± 1.4	6.2± 1.4	0.650
≥90th percentile of % pressure (cmH_2O)	7.7± 1.5	7.6± 1.5	7.7± 1.5	7.7± 1.5	7.7± 1.7	0.791

Data are expressed as means ± standard deviations.

[*]$p < 0.05$, spring; [⁑]$p < 0.05$, summer; [†]$p < 0.05$, to autumn; [‡]$p < 0.05$, winter, repeated-measures analysis of variance.

CPAP = continuous positive airway pressure; AHI = apnea–hypopnea index.

Table 3

Patient characteristics according to CPAP adherence.

Characteristic	Adherent (*n* = 89)	Non-adherent (*n* = 52)	*p*
Sex (male)	75.3 (67)	67.3 (35)	0.307
Age (years)	68.8 ± 10.4	62.0 ± 11.2	<0.001*
Age class (years)			<0.001*
<50	5.6 (5)	9.6 (5)	
50–54	3.4 (3)	21.2 (11)	
55–59	5.6 (5)	11.5 (6)	
60–64	7.9 (7)	17.3 (9)	
65–69	24.7 (22)	15.4 (8)	
70–74	22.5 (20)	13.5 (7)	
≥75	30.3 (27)	11.5 (6)	
BMI (kg/m^2)	24.9 ± 4.0	26.4 ± 5.2	0.089
BMI class (kg/m^2)			
<18.5	3.4 (3)	3.9 (2)	0.629
18.5–25	51.7 (46)	42.3 (22)	
≥25	44.9 (40)	53.9 (28)	
AHI (events/h)	41.4 ± 16.7	42.9 ± 13.2	0.570
AHI severity			
5≤ AHI <15/h	2.2 (2)	0 (0)	0.337
15≤ AHI <30/h	23.6 (21)	15.4 (8)	
AHI ≥30/h	74.2 (66)	84.6 (44)	
JESS score	9.7 ± 5.0	8.9± 4.7	0.377

CPAP use period (years)	3.6 ± 1.3	3.1 ± 1.4	0.052
CPAP use period (years) class			
1≤ years < 2	9.0 (8)	23.1 (12)	0.098
2≤ years <3	15.7 (14)	9.6 (5)	
3≤ years <4	14.6 (13)	21.2 (11)	
4≤ years <5	31.5 (28)	26.9 (14)	
≥5 years	29.2 (26)	19.2 (10)	
Medical history			
Hypertension	34.8 (31)	26.9 (14)	0.331
Diabetes	21.4 (19)	17.3 (9)	0.561
Arrhythmia	12.4 (11)	9.6 (5)	0.868
Heart disease	11.2 (10)	7.7 (4)	0.573
Cerebrovascular disease	5.6 (5)	5.8 (3)	0.098
Employment			
Unemployed	46.1 (41)	38.5 (20)	0.189
Dependent worker	22.5 (20)	34.6 (18)	
Independent worker	21.4 (19)	11.5 (6)	
Homemaker	10.1 (9)	15.4 (8)	
Marital status			
Married/living together	84.3 (75)	86.5 (45)	0.715
Single/living alone	15.7 (14)	13.5 (7)	

Data are expressed as mean ± standard deviation or *total (%) n*. The cutoff point used to define the adherent and non-adherent groups was 70% CPAP use for ≥4 h daily throughout the entire season.

*$p < 0.05$, chi-squared test.

CPAP = continuous positive airway pressure; BMI = body mass index; AHI = apnea–hypopnea index; JESS = Japanese version of the Epworth Sleepiness Scale.

Table 4

CPAP use by season in the adherent and non-adherent groups.

CPAP parameter	**All seasons (ref)**	**Spring**[*]	**Summer**[⁑]	**Autumn**[†]	**Winter**[‡]	***Overall p***
Adherent (*n* = 89)						
Daily use (%)	96.0 ± 5.2	96.4 ± 5.7	95.8 ± 6.9	95.6 ± 7.0	95.8 ± 6.5	0.699
Use for ≥4 h per day (%)	90.3 ± 8.4	91.3 ± 9.0[⁑]	86.4 ± 15.6[*†‡]	90.5 ± 9.0[⁑]	91.4 ± 9.0[⁑]	<0.001
Daily use (min)	382 ± 55	383 ± 57[⁑‡]	367 ± 62[*†‡]	389 ± 58[⁑]	397 ± 60[*⁑]	<0.001
Residual AHI (events/h)	3.0 ± 2.0	2.9 ± 2.0[⁑]	3.4 ± 2.3[*†‡]	2.9 ± 2.0[⁑]	2.8 ± 1.9[⁑]	<0.001
Mean pressure (cmH_2O)	6.0 ± 1.1	6.0 ± 1.2	6.0 ± 1.1	6.0 ± 1.2	6.0 ± 1.2	0.684
≥90th% pressure (cmH_2O)	7.5 ± 1.4	7.5 ± 1.5	7.5 ± 1.4	7.5 ± 1.4	7.5 ± 1.4	0.811
Non-adherent (*n* = 44)						
Daily use (%)	72.3 ± 23.2	76.2 ± 24.0[†]	70.3 ± 25.3	69.2 ± 26.1[*]	72.5 ± 25.1	0.014
Use for ≥4 h per day (%)	44.6 ± 21.0	48.7 ± 22.5[⁑]	42.2 ± 22.5[*]	44.5 ± 24.6	47.8 ± 24.6	0.025
Daily use (min)	270 ± 70	276 ± 75	263 ± 68[‡]	275 ± 74	286 ± 78[⁑]	0.008
Residual AHI (events/h)	3.4 ± 3.1	3.5 ± 3.7	3.8 ± 3.1[‡]	3.3 ± 2.7	3.0 ± 2.4[⁑]	<.0001
Mean pressure (cmH_2O)	6.4 ± 1.4	6.4 ± 1.4	6.5 ± 1.5	6.5 ± 1.6	6.5 ± 1.4	0.265
≥90th% pressure (cmH_2O)	7.9 ± 1.6	7.8 ± 1.6	7.9 ± 1.7	8.0 ± 1.8	8.0 ± 2.0	0.325

Data are expressed as means ± standard deviations. The cutoff point used to define the adherent and non-adherent groups was 70% CPAP use for ≥4 h daily throughout the entire season.

[*] $p < 0.05$, spring; [**] $p < 0.05$, summer; [†] $p < 0.05$, autumn; [‡] $p < 0.05$, winter, repeated-measures analysis of variance

CPAP = continuous positive airway pressure; AHI = apnea–hypopnea index.

Table 5

Associations of clinical features with seasonal CPAP adherence, adjusted for age.

Variable	Spring				Summer				Autumn				Winter			
	Adherent	Non-adherent	OR	95% CI	Adherent	Non-adherent	OR	95% CI	Adherent	Non-adherent	OR	95% CI	Adherent	Non-adherent	OR	95% CI
	n=95 (%)	n=46 (%)			n=82 (%)	n=59 (%)			n=93 (%)	n=48 (%)			n=96 (%)	n=45 (%)		
Age			1.07 *	(1.02, 1.11)			1.06 *	(1.02, 1.10)			1.06 *	(1.03, 1.10)			1.06 *	(1.02 1.10)
Discomfort symptoms																
Nasal allergy	32.6	45.7	0.38	(0.13, 1.09)	13.4	17.0	0.52	(0.13, 2.20)	22.6	18.8	1.03	(0.32, 3.33)	20.8	26.7	1.02	(0.26, 3.99)
Trouble with CPAP use due to nasal allergy	12.6	19.6	1.09	(0.29, 4.15)	9.8	20.3	0.51	(0.14, 1.86)	8.6	8.3	1.14	(0.20, 6.62)	13.5	22.2	0.45	(0.12, 1.68)
Allergy medication use	20.0	23.9	1.80	(0.50, 6.52)	14.6	10.7	2.63	(0.53, 13.15)	14.0	14.6	0.68	(0.16, 2.97)	19.1	21.2	1.22	(0.33, 4.54)
CPAP condensation	17.9	21.7	0.95	(0.27, 3.31)	7.3	10.2	0.84	(0.20, 3.60)	19.4	8.3	7.81 *	(1.48, 41.14)	59.4	48.9	2.74 *	(1.02, 7.35)
Trouble with CPAP use due to condensation	4.2	8.7	0.88	(0.12, 6.36)	7.3	10.2	0.81	(0.19, 3.38)	7.5	10.4	0.17 *	(0.03, 0.97)	28.1	31.1	0.69	(0.24, 2.00)

Bedroom environment factors																
Humidifier	16.8	13.0	1.46	(0.43, 4.96)	8.5	8.5	0.91	(0.22, 3.72)	14.0	18.8	0.49	(0.15, 1.63)	26.0	26.7	1.12	(0.42, 3.01)
Dehumidifier	3.2	0.0	8.79	(0.09, 900.77)	9.8	3.4	2.44	(0.47, 12.75)	4.3	2.1	1.45	(0.14, 15.45)	4.2	6.7	0.54	(0.09, 3.29)
Air conditioner	21.1	23.9	0.87	(0.34, 2.24)	57.3	62.7	1.21	(0.54, 2.71)	39.8	43.8	1.18	(0.51, 2.74)	46.9	57.8	0.90	(0.40, 2.04)
Heater	11.2	5.8	2.22	(0.37, 13.39)	0.0	0.0	_	_	12.4	7.7	3.52	(0.76, 16.33)	28.1	308	1.08	(0.43, 2.72)
Floor heating	2.1	6.5	0.15	(0.01, 1.75)	0.0	0.0	_	_	3.2	2.1	3.07	(0.12, 78.42)	6.3	11.1	0.84	(0.20, 3.47)
Electric fan	6.3	4.4	1.81	(0.19, 17.25)	45.1	59.3	0.67	(0.32, 1.40)	21.5	45.8	0.29 *	(0.11, 0.73)	2.1	0.0	5.36	(0.05, 584.24)
Bed temperature regulator	16.8	8.7	1.63	(0.47, 5.64)	0.0	3.4	0.42	(0.01, 19.91)	11.8	1.4	0.88	(0.24, 3.23)	41.7	24.4	1.93	(0.77, 4.84)
CPAP device features																
Humidifier	56.8	63.0	0.87	(0.24, 3.18)	54.9	64.4	0.69	(0.18, 2.57)	55.9	64.6	0.42	(0.11, 1.55)	56.3	64.4	0.68	(0.18, 2.61)
Heated tube	47.4	50.0	0.74	(0.20, 2.17)	46.3	50.9	0.92	(0.25, 3.39)	47.3	50.0	1.26	(0.34, 4.68)	45.8	53.3	0.72	(0.19, 2.68)

The adherent group served as the reference. The full model included all covariates listed.

*$p < 0.05$ for regression analysis.

CPAP = continuous positive airway pressure; OR = odds ratio; CI = confidence interval.