**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*.

**Disclosure statement**

**Number of tables:** 5

**Number of figures:** 0

**Abstract word count:** 235

**Main text word count:** 3248

**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 $\geq$ 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 $\geq$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 $\geq$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.

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# 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

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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 $\geq$ 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

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

The mean BMI was $25.5 \pm 4.5$ kg/m$^2$ and did not differ significantly between men and women ($25.5 \pm 4.2$ and $25.5 \pm 5.2$ kg/m$^2$, respectively). The mean AHI was $41.9 \pm 15.5$ events/h and was significantly higher among men than among women ($43.7 \pm 16.4$ vs. $37.4 \pm 11.9$ events/h; $p = 0.014$). Most (78.0%) patients had severe OSA (AHI $\geq 30$ 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 $9.4 \pm 4.9$, and was significantly higher among men than among women ($10.0 \pm 4.9$ vs. $7.8 \pm 5.1$; $p = 0.019$). 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 $\geq 4$ 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 ($3.6 \pm 1.3$ vs. $3.1 \pm 1.4$ 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 ($263 \pm 68$ vs. $286 \pm 78$ min, $p = 0.008$), and the residual AHI was highest in summer and lowest in winter ($3.8 \pm 3.1$ vs. $3.0 \pm 2.4$ 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

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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 |

**Acknowledgements**

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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/m$^2$)** | 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) | |

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| | | |
|---|---|---|
| **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$_2$O) | 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$_2$O) | 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 $\pm$ standard deviation or *total (%) n*. The cutoff point used to define the adherent and non-adherent groups was 70% CPAP use for $\geq$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$_2$O) | 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$_2$O) | 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$_2$O) | 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$_2$O) | 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 $\pm$ standard deviations. The cutoff point used to define the adherent and non-adherent groups was 70% CPAP use for $\geq 4$ 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.