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Association between patient-perceived and device-recorded continuous positive airway pressure usage discrepancy and sleep restfulness in patients with obstructive sleep apnea receiving continuous positive airway pressure therapy

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Abstract

Purpose

Clinical management of obstructive sleep apnea (OSA) primarily relies on device-recorded continuous positive airway pressure (CPAP) usage duration. However, a discrepancy frequently exists between objectively recorded and patient-reported CPAP usage duration. This study aimed to investigate the association between sleep restfulness and the discrepancy between subjective and objective CPAP usage durations in patients undergoing CPAP therapy.

Methods

This multicenter, prospective, questionnaire-based study evaluated sleep-related parameters, including subjective sleep latency, subjective CPAP usage duration, and sleep restfulness. Sleep restfulness was assessed using a 5-point Likert-type scale, with a score of 5 denoting the highest degree of restfulness, and the score of 5 was defined as restfulness. The discrepancy was calculated as subjective minus objective daily CPAP usage duration.

Results

Of the 1,043 patients surveyed, 906 were included in the final analysis. The median subjective sleep latency was 15 (10–30) minutes, whereas the median discrepancy between subjective and objective CPAP usage duration was 6 (− 32 to 21) minutes. Multivariate logistic regression analysis demonstrated that a shorter subjective sleep latency (≤ 10 minutes) and a greater positive discrepancy between subjective and objective CPAP usage duration (> 21 minutes) were independently and positively associated with sleep restfulness.

Conclusions

The discrepancy between subjective and objective CPAP usage duration is independently associated with sleep restfulness in patients with OSA. Clinical assessment should incorporate patients' subjective perception of CPAP use rather than relying exclusively on objectively recorded device data to help them achieve greater sleep restfulness.

Introduction

Obstructive sleep apnea (OSA) is a prevalent sleep-related breathing disorder. A recent study estimated that approximately 900 million adults aged 30–69 years worldwide have OSA [1]. OSA is characterized by recurrent episodes of upper-airway obstruction during sleep, resulting in intermittent hypoxemia, hypercapnia, sleep fragmentation, recurrent nocturnal arousals, increased respiratory effort, and heightened sympathetic nervous system activity [2]. Consequently, OSA is commonly associated with daytime symptoms, including a lack of sleep restfulness, excessive daytime sleepiness, cognitive impairment, and reduced concentration [3], and serves as an independent risk factor for cardiovascular disease [4]. Continuous positive airway pressure (CPAP) therapy, which is the gold standard treatment for OSA, can alleviate these daytime symptoms and reduce cardiovascular morbidity and mortality [4]. However, insufficient adherence to CPAP therapy attenuates these therapeutic benefits and is associated with an increased risk of cardiovascular events and mortality [5–9].

Good adherence to CPAP therapy is conventionally defined as device use for at least 4 hours per night on at least 70% of nights over a 1-month period [10]. CPAP-related parameters—including the number of usage days, usage duration, pressure fluctuations, and the apnea–hypopnea index (AHI)—can be accessed through the device display or remotely monitored using smartphone applications, such as myAir and DreamMapper. However, in clinical practice, a discrepancy often exists between the CPAP usage duration reported by patients (subjective CPAP usage duration) and that objectively recorded by the CPAP device (objective CPAP usage duration). Previous studies have reported that patients tend to overestimate their CPAP usage duration by approximately 1 hour compared with objectively recorded device data [11, 12].

Hamada et al. demonstrated that sleep restfulness is independently associated with objective CPAP usage duration [6]. However, whether sleep restfulness is associated with the discrepancy between subjective and objective CPAP usage durations remains unclear. Therefore, this study aimed to investigate the association between sleep restfulness and the discrepancy between subjective and objective CPAP usage duration using data from a multicenter prospective questionnaire-based survey.

Methods

Participants

This prospective multicenter study was conducted at Kyoto University Hospital, Rakuwakai Otowa Hospital, Kyoto Minami Hospital, Shin Kyoto Minami Hospital, Hatta Medical Clinic, Shibata Clinic, Uchihama Clinic, and Ooka Clinic, Inari Office. The study flowchart is shown in Fig. 1. Between

February and December 2025, sleep-related questionnaires were administered to 1,043 patients with OSA receiving CPAP therapy. The study protocol was approved by the Ethics Committee of Kyoto University Graduate School and Faculty of Medicine (approval no. R4753; approval date: December 16, 2024). Written informed consent was obtained from all participants. Data on clinical characteristics–including age, body mass index, comorbidities (hypertension, dyslipidemia, diabetes mellitus, chronic kidney disease, ischemic heart disease, stroke, and arrhythmia), the AHI before CPAP therapy initiation, and the duration of CPAP therapy–were extracted from medical records.

CPAP Therapy and Devices

Information on CPAP therapy, including device manufacturer (Philips Respironics [Murrysville, Pennsylvania, USA], ResMed [Sydney, Australia], or other manufacturers including Fisher & Paykel Healthcare [Auckland, New Zealand], Sefam [Nancy, France], Resvent Medical Technology [Shenzhen, China], and Koike Medical [Kobe, Japan]), pressure mode (auto-adjusting or fixed), and interface type (nasal, nasal pillow, or oronasal), was obtained from medical records. CPAP device data, including the AHI, mean CPAP usage duration on nights of device use, and leak level, were downloaded for the 1-month period preceding administration of the sleep-related questionnaire. Good adherence to CPAP therapy was defined as device use for at least 4 hours per night on 70% of nights within a 1-month period [10]. A large leak was defined as a leak duration of > 1 hour for Philips Respironics and Fisher & Paykel Healthcare devices, or a 95th percentile leak rate of > 24 L/min for nasal-pillow interface and > 36 L/min for oronasal interface when using ResMed, Sefam, Resvent Medical Technology, or Koike Medical devices [13].

Sleep-Related Questionnaire

The sleep-related questionnaire included the Japanese version of the Epworth Sleepiness Scale (JESS), subjective sleep duration, subjective sleep latency, subjective CPAP usage duration, sleep restfulness, and the use of sleep medications during the preceding month. The JESS is a self-administered, 8-item questionnaire designed to assess daytime sleepiness [14]. Patients rated their usual likelihood of dozing off or falling asleep during eight everyday activities on a 4-point scale ranging from 0 to 3. Total JESS scores range from 0 to 24, with higher scores indicating a greater propensity for daytime drowsiness. A JESS score of ≥ 11 was considered indicative of subjective excessive daytime sleepiness. Sleep restfulness was rated on a 5-point Likert-type scale, with the score of 5 indicating restfulness (1 = restless; 2 = somewhat restless; 3 = neither restless nor restful; 4 = somewhat restful; 5 = restful) [6, 15, 16].

Statistical Analysis

Continuous variables were expressed as medians with interquartile ranges, while categorical variables were expressed as frequencies. All statistical analyses were performed using JMP Pro 18 software (SAS Institute, Cary, NC, USA). First, clinical characteristics, sleep-related questionnaire responses, CPAP therapy parameters, and CPAP device data were compared across sleep restfulness scores using univariate analyses. The Jonckheere–Terpstra test was utilized to assess trends in continuous variables. For categorical variables, the Cochran–Armitage test for trend was used when comparing two ordered groups, whereas the chi-square test was used for comparing among three groups. Second, multivariate logistic regression analysis was performed to identify factors independently associated with sleep restfulness. Variables with a *p*-value of less than 0.05 in the univariate analyses were entered into the multivariate model. Continuous variables were categorized into quartiles, and the upper or lower quartile, as appropriate, was entered into the multivariate analysis. A two-sided *p*-value of less than 0.05 was considered statistically significant.

Results

Participants

As shown in the study flowchart (Fig. 1), sleep-related questionnaires were administered to 1,043 patients with OSA receiving CPAP therapy. Of these, 137 patients were excluded because of missing data on clinical characteristics (*n* = 1), sleep-related questionnaire scores (*n* = 83), CPAP therapy details (*n* = 14), or CPAP device parameters (*n* = 39). Ultimately, 906 patients were included in the analysis.

Table 1 summarizes the baseline characteristics, sleep-related questionnaire scores, CPAP therapy details, and CPAP device parameters of the study cohort. The cohort comprised 722 (79.7%) men and 184 (20.3%) women, with a median body mass index of 26.6 (24.2–30.0) kg/m^2. The prevalence of comorbidities was as follows: hypertension, 65.5%; dyslipidemia, 48.3%; diabetes mellitus, 26.8%; chronic kidney disease, 16.7%; ischemic heart disease, 9.2%; stroke, 9.9%; and arrhythmia, 14.2%. Overall, 140 (15.5%) patients reported using sleep medications, whereas 738 (81.5%) had a JESS score of < 11, indicating no subjective excessive daytime sleepiness. Regarding CPAP devices, 363 (40.1%) patients used Philips Respironics devices, 510 (56.3%) used ResMed devices, and 33 (3.6%) used devices from other manufacturers. The median residual AHI was 1.7 (0.9–3.2) events/hour, and only 20 (2.2%) patients had an AHI of ≥ 10 events/hour. Good CPAP adherence was achieved by 625 (69.0%) patients. Regarding sleep restfulness, 38 (4.1%), 143 (15.8%), 182 (20.1%), 335 (37.0%), and 208 (23.0%) patients reported feeling restless, somewhat restless, neither restless nor restful, somewhat restful, and restful, respectively. The median subjective sleep latency was 15 (10–30) min, and the median subjective sleep duration was 360 (300–420) minutes. The median discrepancy between subjective and objectively recorded CPAP usage durations—calculated as subjective CPAP usage duration obtained from a sleep-related questionnaire minus the mean CPAP usage duration on nights of device use obtained from CPAP device data—was 6 (− 32 to 21) minutes.

Table 1
Differences in clinical characteristics, sleep-related questionnaire responses, CPAP therapy parameters, and CPAP device data according to sleep restfulness score

	Total	Sleep restfulness score[1]					P_{trend} value
		1	2	3	4	5	
Number	906	38	143	182	335	208	
Clinical characteristics							
Sex, male/female, n (%)	722/184 (79.7/20.3)	27/11 (71.1/28.9)	107/36 (74.8/25.2)	143/39 (78.6/21.4)	274/61 (81.8/18.2)	171/37 (82.2/17.8)	0.023
Age, y	66 (57, 74)	66 (55, 74)	64 (55, 74)	65 (56, 73)	66 (58, 73)	68 (58, 76)	0.014
BMI, kg/m^2	26.6 (24.2, 30.0)	27.2 (25.3, 30.6)	26.3 (24.3, 29.4)	27.5 (24.6, 30.5)	26.4 (24.0, 29.5)	26.8 (23.8, 30.1)	0.40
Comorbidities							
Hypertension, n (%)	593 (65.5)	24 (63.2)	86 (60.1)	122 (67.0)	220 (65.7)	141 (67.8)	0.22
Dyslipidemia, n (%)	438 (48.3)	13 (34.2)	63 (44.1)	102 (56.0)	162 (48.4)	98 (47.1)	0.49
Diabetes mellitus, n (%)	243 (26.8)	7 (18.4)	30 (21.0)	55 (30.2)	95 (28.4)	56 (26.9)	0.17
Chronic kidney disease, n (%)	151 (16.7)	8 (21.1)	27 (18.9)	29 (15.9)	57 (17.0)	30 (14.4)	0.25
Ischemic heart disease, n (%)	83 (9.2)	3 (7.9)	12 (8.4)	19 (10.4)	35 (10.5)	14 (6.7)	0.70
Stroke, n (%)	68 (7.5)	4 (10.5)	15 (10.5)	9 (5.0)	26 (7.8)	14 (6.7)	0.32
Arrhythmia, n (%)	129 (14.2)	6 (15.8)	16 (11.2)	20 (11.0)	59 (17.6)	28 (13.5)	0.34
Sleep-related questionnaire							
Sleep medication use, n (%)	140 (15.5)	14 (36.8)	35 (24.5)	22 (12.1)	48 (14.3)	21 (10.1)	< 0.0001
Subjective sleep latency, min	15 (10, 30)	15 (8.8, 30)	15 (10, 30)	15 (10, 30)	15 (10, 30)	10 (5, 20)	< 0.0001
Subjective sleep duration, h	360 (300, 420)	300 (240, 360)	360 (300, 420)	360 (300, 420)	360 (330, 420)	390 (360, 420)	< 0.0001
Subjective CPAP usage duration, min	360 (300, 390)	255 (237, 352.5)	300 (240, 360)	330 (267.5, 393)	360 (300, 400)	360 (300, 420)	< 0.0001
JESS score	6 (4, 9)	9 (5.8, 12.3)	7 (5, 10)	8 (5, 10)	6 (3, 9)	5 (3, 8)	< 0.0001
JESS score of < 11, n (%)	738 (81.5)	23 (60.5)	109 (76.2)	143 (78.6)	277 (82.7)	186 (89.4)	< 0.0001
CPAP therapy							
AHI before CPAP therapy initiation,[2] events/h	40.5 (28.1, 52.3)	37.9 (27.9, 52.6)	38.6 (24.7, 49.4)	42.9 (29.2, 57.9)	38.6 (27.9, 48.7)	43.6 (30.3, 56)	0.058
Duration after CPAP therapy initiation, mon	78 (37, 134.3)	91 (42.8, 139.8)	68 (36, 134)	76.5 (32.8, 138.3)	82 (35, 138)	78.5 (41, 133)	0.50
CPAP devices, Philips Respironics /ResMed/Others,[3] n (%)	363/510/33 (40.1/56.3/3.6)	14/24/0 (36.8/63.2/0)	54/83/6 (37.8/58.0/4.2)	77/102/3 (42.3/56.0/1.7)	137/182/16 (40.9/54.3/4.8)	81/119/8 (38.9/57.2/3.8)	0.46[6]
Pressure settings, auto-adjusting/fixed, n (%)	840/66 (92.7/7.3)	34/4 (89.5/10.5)	129/14 (90.2/9.8)	169/13 (92.9/7.1)	310/25 (92.5/7.5)	198/10 (95.2/4.8)	0.074

	Total	Sleep restfulness score[1]					P_{trend} value
		1	2	3	4	5	
Interface, nasal/pillow/oronasal, n (%)	776/83/47 (85.7/9.1/5.2)	32/4/2 (84.2/10.5/5.3)	119/18/6 (83.2/12.6/4.2)	160/12/10 (87.9/5.5/6.6)	280/36/19 (83.6/10.7/5.7)	185/15/8 (88.9/7.2/3.9)	0.33[6]
CPAP device parameters							
AHI, events/h	1.7 (0.9, 3.2)	1.8 (0.8, 3.5)	1.6 (0.8, 3.5)	1.8 (0.9, 3.5)	1.6 (0.8, 3)	1.8 (0.9, 3.1)	0.80
Mean CPAP usage duration on nights of device use, min/day	345 (284.8, 401)	278 (234.3, 337.8)	328 (267, 396)	333 (260.5, 398)	356 (299, 402)	359 (314.3, 407.8)	< 0.0001
Large leak, n (%)	229 (25.3)	8 (21.1)	37 (25.9)	60 (33.0)	80 (23.9)	44 (21.2)	0.19
Good adherence,[4] n (%)	625 (69.0)	17 (44.7)	92 (64.3)	113 (62.1)	238 (71.0)	165 (79.3)	< 0.0001
Discrepancy between subjective and objective CPAP usage duration,[5] min	−6 (−32, 21)	−12.5 (−44.8, 14.8)	−11 (−43, 16)	−8.5 (−34.3, 21.3)	−3 (−30, 21)	−2.5 (−28.8, 25.8)	0.013

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

Data were expressed as median with an interquartile range for continuous variables or frequencies for categorical variables.

[1]Sleep restfulness was rated using a 5-point Likert-type scale, with the score of 5 indicating restfulness (1 = restless; 2 = somewhat restless; 3 = neither; 4 = somewhat restful; 5 = restful).

[2]Before initiating CPAP therapy, 717 (79.1%) patients underwent polysomnography, whereas 176 (19.4%) underwent portable monitoring. The diagnostic modality (polysomnography or portable monitor) used for the remaining 13 (1.4%) patients was unclear.

[3]Other devices included those manufactured by Fisher & Paykel, Sefam, Resvent, and Koike Medical.

[4]Good adherence to CPAP therapy was defined as CPAP use for at least 4 hours per night on 70% of nights over a 1-month period.

[5]Discrepancy = subjective CPAP usage duration (obtained from sleep-related questionnaire)–mean CPAP usage duration on nights of CPAP use (obtained from CPAP device data)

[6]Chi-square test

Sleep Restfulness

Table 1 shows the variations in clinical characteristics, sleep-related questionnaire scores, CPAP therapy details, and CPAP device parameters across the sleep restfulness scores. Subjective sleep duration showed a significantly increasing trend as sleep restfulness score rose (300 [240–360] minutes, 360 [300–420] minutes, 360 [300–420] minutes, 360 [330–420] minutes, and 390 [360–420] minutes, respectively; P_{trend} <0.0001). Conversely, subjective sleep latency showed significantly decreasing trend as sleep restfulness scores increased (15 [8.8–39] minutes, 15 [10–30] minutes, 15 [10–30] minutes, 15 [10–30] minutes, and 10 [5–20] minutes, respectively; P_{trend} <0.0001; Fig. 2A). Notably, the discrepancy between subjective and objectively recorded CPAP usage durations exhibited a significantly increasing trend with increasing sleep restfulness scores (− 12.5 [−44.8 to 14.8] minutes, − 11 [−43 to 16] minutes, − 8.5 [− 34.3 to 21.3] minutes, − 3 [− 30 to 21] minutes, and − 2.5 [− 28.8 to 25.8] minutes, respectively; P_{trend} = 0.013; Fig. 2B).

Table 2 presents the results of the multivariable logistic regression analysis of factors associated with sleep restfulness. Older age (> 65 years), sleep medication use, shorter subjective sleep latency (≤ 10 minutes), a JESS score of < 11, good adherence to CPAP therapy, longer subjective sleep duration (> 420 minutes), and a greater discrepancy between subjective and objectively recorded CPAP usage duration (> 21 minutes) were independently and positively associated with sleep restfulness.

Table 2
Multivariate logistic regression analysis of factors associated with high sleep restfulness

	Model 1		Model 2		Model 3	
	Odds ratio (CI)	***P*-value**	**Odds ratio (CI)**	***P*-value**	**Odds ratio (CI)**	***P*-value**
Age > 65 y	1.70 (1.17, 2.46)	0.0049	1.80 (1.25, 2.59)	0.0016	1.81 (1.26, 2.60)	0.0014
Sex (male)	0.97 (0.64, 1.48)	0.90	0.98 (0.65, 1.49)	0.93	0.99 (0.65, 1.50)	0.95
Sleep medication use	0.54 (0.32, 0.91)	0.021	0.55 (0.33, 0.92)	0.023	0.55 (0.33, 0.92)	0.024
Subjective sleep latency ≤ 10 min	1.97 (1.41, 2.74)	< 0.0001	1.94 (1.39, 2.70)	< 0.0001	1.94 (1.39, 2.70)	< 0.0001
JESS score of < 11	2.12 (1.24, 2.74)	0.0026	2.16 (1.32, 3.52)	0.0022	2.16 (1.32, 3.54)	0.0021
Good adherence	1.84 (1.24, 2.74)	0.0025	1.85 (1.22, 2.80)	0.0035	1.88 (1.24, 2.83)	0.0027
Subjective sleep duration > 420 min	1.62 (1.05, 2.50)	0.029	-	-	-	-
Subjective CPAP usage duration > 390 min	-	-	1.14 (0.77, 1.68)	0.50	-	-
Mean CPAP usage duration on nights of device use > 401 min	-	-	-	-	1.10 (0.75, 1.62)	0.61
Discrepancy between subjective and objective CPAP usage duration [1] >21 min	1.39 (0.95, 2.04)	0.089	1.44 (0.97, 2.12)	0.069	1.49 (1.02, 2.18)	0.038

CI = confidence interval; CPAP = continuous positive airway pressure; JESS = Japanese version of the Epworth Sleep Scale.

[1](subjective CPAP usage duration obtained from sleep-related questionnaire) – (mean CPAP usage duration on the days used obtained from CPAP device).

Discussions

The present study provides novel evidence that the discrepancy between subjective and objectively recorded CPAP usage duration is independently associated with sleep restfulness in patients with OSA receiving CPAP therapy. Since CPAP therapy may enhance sleep restfulness and patients' satisfaction with therapy, patients may consequently overestimate their actual CPAP usage duration. Additionally, shorter subjective sleep latency was independently associated with greater sleep restfulness. Although clinical CPAP management typically prioritizes device-recorded (objective) usage duration, our findings suggest that to promote greater sleep restfulness, clinical assessment and guidance should also incorporate patients' subjective perceptions of their CPAP usage duration.

In this study, the median discrepancy between subjective and objectively recorded CPAP usage durations was − 6 (− 32 to 21) minutes. Previous studies have reported that patients typically overestimate CPAP usage duration by approximately 1 hour compared with objective device records [11, 12]. Compared with these historical cohorts, our study population demonstrated a noticeably smaller discrepancy. However, the earlier studies examined patients approximately 1–2 years post-CPAP initiation and were conducted more than two decades ago [11, 12]. In contemporary, clinical practice, patients can actively monitor their CPAP adherence *via* smartphone applications, which may have heightened their awareness of actual usage time and consequently minimized the discrepancy between subjective and objective measurements.

Subjective sleep latency was also independently associated with sleep restfulness. Sleep latency is a critical indicator of sleep quality, and prolonged sleep latency has been linked to adverse health outcomes, including poorer mental health, hypertension, and increased mortality risk [17, 18]. Although a sleep latency of 10–20 minutes is generally considered typical among healthy individuals [17], CPAP initiation may paradoxically prolong sleep latency in some patients [19]. In our cohort, the median subjective sleep latency was 15 (10–30) minutes, which aligns closely with healthy norms. Future longitudinal studies tracking concurrent changes in sleep latency and sleep restfulness before and after CPAP initiation are warranted to clarify this relationship further.

This study has several limitations. First, its cross-sectional design precludes causal interference; therefore, it remains unclear whether interventions targeting the discrepancy between subjective and objectively recorded CPAP usage would directly improve sleep restfulness. Second, we did not collect detailed information on the specific classes of sleep-related medications used by participants, including benzodiazepines, non-benzodiazepine hypnotics, melatonin receptor agonists, antidepressants, antipsychotics, and anticonvulsants. Third, sleep duration and latency were

assessed using subjective questionnaires, without objective confirmation *via* polysomnography or actigraphy. Future research should investigate whether discrepancies between subjective and objectively measured sleep latency similarly influence patient-reported sleep restfulness.

Conclusions

The discrepancy between subjective and objective recorded CPAP usage duration is independently associated with sleep restfulness in patients with OSA receiving CPAP therapy. To optimize patients' perceived sleep restfulness, clinicians should look beyond objective compliance metrics and actively consider patients' subjective perceptions of CPAP usage duration in clinical assessment and management.

Abbreviations

AHI
apnea–hypopnea index
BMI
body mass index
CI
confidence interval
CPAP
continuous positive airway pressure
JESS
Japanese version of the Epworth Sleep Scale
OSA
obstructive sleep apnea

Declarations

Competing Interests:

Satoshi Hamada and Kimihiko Murase received research grants from Teijin Pharma outside the submitted work.

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Michiko Tsuchiya, Nobuhiro Shibata, Fuyuko Hatta, Yasuhisa Sintani, Hisashi Ooka, and Yukio Nagasaka haveno conflict of interest.

Financial conflicts:

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Author contributions:

All authors contributed to the study conception and design. Data collection was performed by all authors. Data analysis was performed by Satoshi Hamada and Susumu Sato. The first draft of the manuscript was written by Satoshi Hamada and Susumu Sato, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Consent to participate:

Informed consent was obtained from all individuals participants included in the study.

Ethics approval:

The study protocol was approved by the Ethics Committee of Kyoto University Graduate School and Faculty of Medicine (approval no. R4753; approval date: December 16, 2024).

Declaration of generative AI in scientific writing

We did not use any generative artificial intelligence software or tool for producing this manuscript.

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Figures

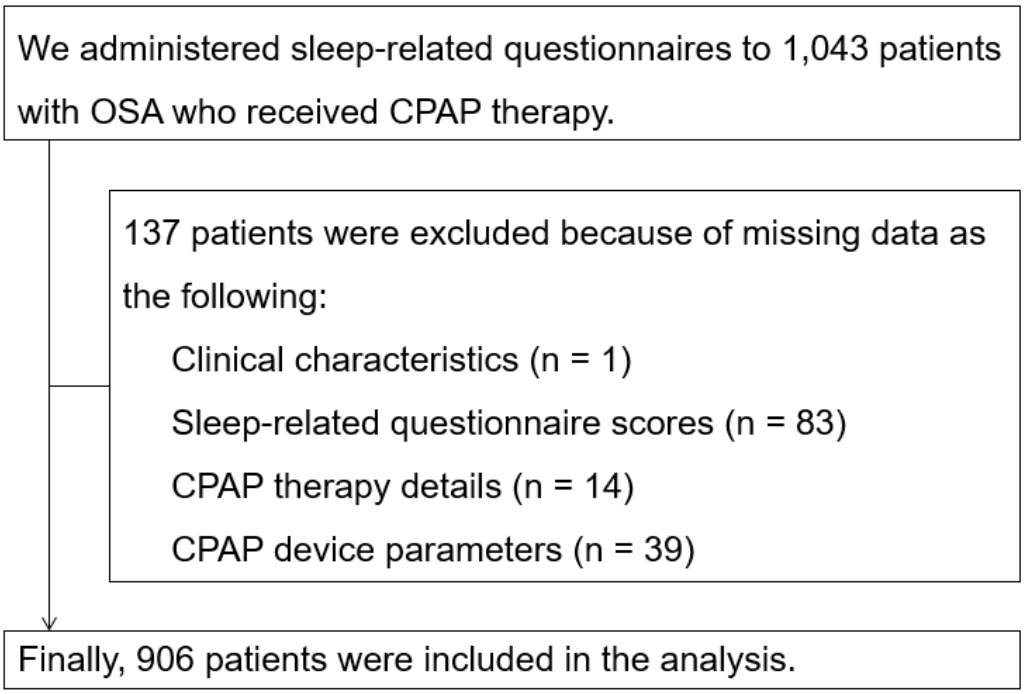


Figure 1

Study flowchart.

CPAP = continuous positive airway pressure; OSA = obstructive sleep apnea.

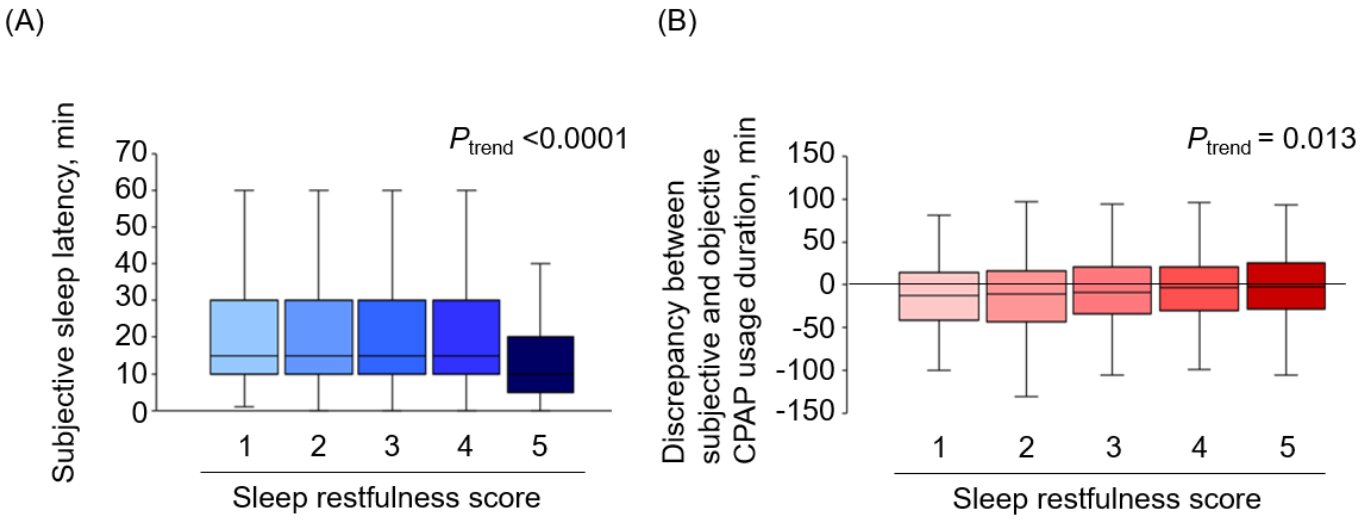


Figure 2

Difference in subjective sleep latency (A) and discrepancy between subjective and objective CPAP usage duration (B) according to sleep restfulness score.

CPAP = continuous positive airway pressure.