Diagnostic accuracy of daytime polysomnography: a reappraisal during the COVID-19 era

Mahismita Patro,[1] Nipun Malhotra,[2] Dipti Gothi,[2] Rahul Kumar,[2] Ganjam Yasasvini[2]

[1]Department of Pulmonary and Sleep Medicine, All India Institute of Medical Sciences, Bhubaneswar; [2]Department of Pulmonary and Sleep Medicine, Postgraduate Institute of Medical Sciences and Research and Employees State Insurance Model Hospital, New Delhi, India

Correspondence: Dipti Gothi, Department of Pulmonary and Sleep Medicine, Postgraduate Institute of Medical Sciences and Research and Employees State Insurance Model Hospital, Basaidarapur, New Delhi 110015, India. E-mail: diptigothi@gmail.com

Key words: nighttime, nocturnal, conventional, CPAP, OSA, apnea-hypopnea.

Contributions: MP, conception, conduct, data recording, writing, reviewing, and editing; DG, conception, supervision, writing, reviewing, and editing; NM, conduct, data recording, analysis, writing, reviewing, and editing; RK, GY, data recording and reviewing. All authors have substantially contributed to the research, have given their final approval of the version submitted for publication, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of interest: the authors declare that they have no competing interests, and all authors confirm accuracy.

Ethics approval and consent to participate: the research was approved by the institutional ethics committee (ESIPGIMSR-2022053). Consent for participation was obtained from each participating individual.

Informed consent: written informed consent was obtained from all participating individuals or their authorized representatives for information to be used in an anonymized manner and for scientific publication.

Patient consent for publication: the consent for publication was part of the informed consent form and is therefore, being reflected here.

Availability of data and materials: data is available from the corresponding author upon request.

Funding: no funding was required for the conduct of this research. It was covered under the 'Health and social benefits scheme' of the Employees' State Insurance of the Government of India.

Received: 4 February 2024.
Accepted: 14 February 2024.
Early view: 29 February 2024.

Publisher's note: all claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article or claim that may be made by its manufacturer is not guaranteed or endorsed by the publisher.

Licensee PAGEPress, Italy
Monaldi Archives for Chest Disease 2025; 95:2945
doi: 10.4081/monaldi.2024.2945

Abstract

Level I conventional polysomnography (PSG), the gold standard for diagnosing obstructive sleep apnea (OSA), requires an overnight stay. This study evaluated the role of daytime PSG as an alternative diagnostic tool. A prospective cohort study was undertaken with consecutive patients with suspected OSA at a tertiary care sleep center. The primary objective was to evaluate the sensitivity and diagnostic accuracy of daytime PSG for diagnosing OSA. The secondary objective was to find out the factors associated with a falsely negative daytime PSG result. All individuals were subjected to level I daytime PSG, done in the sleep lab in the presence of an experienced sleep technician during the daytime from 12 PM to 4 PM. Out of 162 patients, 105 underwent daytime PSG. OSA was diagnosed on daytime PSG in 86. Of the remaining 19 patients, 7 refused a repeat PSG study. Out of the 12 individuals who underwent the nighttime PSG for confirmatory diagnosis, 10 were diagnosed as OSA (false negatives), and 2 were confirmed as non-OSA (true negatives). The sensitivity, diagnostic accuracy, and negative predictive value of daytime PSG were 89.58%, 89.80%, and 16.67%, respectively. The false negatives had a higher prevalence of mild OSA. Daytime PSG is sensitive in diagnosing OSA and can be considered in individuals with severe symptoms at centers with a high patient load or when the individual wishes to avoid a nighttime study. A negative result in daytime PSG must be followed by conventional overnight PSG for confirmatory diagnosis.

Introduction

Obstructive sleep apnea (OSA) is a type of sleep-related breathing disorder characterized by a repeatedly interrupted airflow caused by an upper airway impediment [1]. These recurrent interruptions manifest as apneas and hypopneas and contribute to significant morbidity and mortality. OSA is a common disease affecting 5-35% of the population worldwide and 14% of Indians [1,2]. However, it is underdiagnosed in India due to a lack of awareness about the disease. Further, there is a gross mismatch in the number of sleep-related tests performed compared to the large at-risk population of the country [3].

OSA is diagnosed using polysomnography (PSG) [3]. This can be done either in-lab (level I) or out-of-center (levels II/III/IV) [3]. Level I PSG is considered the gold standard to diagnose sleep-related breathing disorders [3]. It is recommended for comorbid sleep disorders, positive airway pressure titration, sleep-related behavior disorders, narcolepsy, nocturnal seizures, periodic limb movement disorders, unstable medical conditions, or after oral appliance use [3]. Additionally, level I PSG is also recommended for patients with previous negative reports on levels II-IV studies [3]. Level I study mandates the overnight presence of a sleep technician. So, the cost

of an overnight PSG is high. Further, the waiting times for level I PSG are long. To circumvent this, out-of-center PSG has been advocated. However, these unsupervised study types have flaws of their own [4]. They are indicated for a subset of OSA with severe clinical symptoms and an urgent need for treatment initiation, but where level I PSG is not readily available. These may also be advisable for patients unable to attend a sleep laboratory due to safety or mobility issues [3,4]. The level III/IV PSGs do not have electroencephalogram recording and, therefore, use monitored time rather than actual total sleep time for calculation of Apnea Hypopnea Index (AHI) [3]. This results in an underestimation of the severity of OSA [4]. Further, the overcrowded home of an average Indian family may not be conducive to home-based sleep testing. Lastly, newer out-of-center sleep devices require smartphones for functioning, which many patients in India are either unable to operate or afford [5]. So, both level I and level II/III/IV studies have their own disadvantages.

The COVID-19 pandemic began in December 2019 [6]. There was an exponential rise in the number of cases. To flatten the curve, nations repeatedly implemented lockdowns. During these periods, routine and non-emergent diagnostic procedures were suspended. In India, sleep labs were operationally shut down, as per national guidance for non-emergent diagnostic procedures, during the peaks of the second and third COVID-19 pandemic waves (April 2021 to May 2021 and January 2022 to February 2022) [7,8]. Patients requiring PSG queued up over time, and waiting times surged to 6 months or greater. To address this issue without compromising the diagnostic accuracy of a level I PSG, we decided to use daytime PSG as an alternative to nighttime PSG in individuals with high pretest probability for OSA. We chose daytime PSG as our preferred alternative because of the following practical advantages: i) it remains a level I PSG conducted in the presence of a sleep technician; ii) there is no additional cost borne by the laboratory for acquiring new technology, such as level IV PSG devices; iii) the effect of unwanted disturbance, such as due to overcrowding or residential surroundings, on an out-of-center PSG conducted at the patient's home is avoided; iv) most importantly, however, a successful daytime study was expected to reduce the discomfort of an overnight stay for the patient and their accompanying relative, making it more acceptable to the patient. To this end, we performed a literature search, which yielded only a few studies on daytime PSG. All of them had been conducted at least 10 years prior and on a small number of patients. These studies had found a specificity of 88-100% and a sensitivity of at least 66% for diagnosing OSA [9-14]. The reason for the abandonment of daytime PSG despite evidence of its positive outcomes is unclear. In light of the above concerns, we conducted this study as a re-evaluation of daytime PSG in diagnosing OSA, within the COVID-19 pandemic period. The primary objective was to find the sensitivity and diagnostic accuracy of daytime PSG for diagnosing OSA. The secondary objective was to find the factors associated with a falsely negative daytime PSG leading to a need for conventional nighttime PSG. The study adheres to the STARD list from the EQUATOR network..

Materials and Methods

This was a prospective study conducted at a tertiary care institution with specialized experience in sleep medicine in India. The institution is part of the Employees' State Insurance Scheme under the Government of India, which provides health and social support to factory workers and laborers. The study protocol and patient consent documents were approved by the institutional ethical committee (ESIPGIMSR-2022053). The study was conducted between June 2020 and December 2022.

Consecutive patients aged 18 years or above presenting to the outpatient facilities at the department of pulmonary, sleep, and critical care medicine of the institute with symptoms of OSA were included in the study. These individuals were assessed thoroughly for sleep-related history and laboratory investigations for possible systemic comorbid illnesses. The patients were also assessed for the coexistence of insomnia and restless leg syndrome as per standard guidelines. The participants were then risk-stratified for OSA using STOP-Bang, Epworth Sleepiness Scale (ESS), and Perioperative Sleep Apnea Prediction (PSAP) scoring criteria. Patients were taken up for daytime PSG study if they scored positive on any of the three scores, *i.e.*, STOP-Bang>3, ESS>10, or PSAP>4 [15-17]. The exclusion criteria were: individuals unable to sleep during the day, significant uncontrolled systemic illness, moribund status, exacerbation of chronic illnesses like chronic obstructive pulmonary disease or heart failure within the previous month, or lack of social support.

All individuals undergoing daytime PSG were counseled meticulously regarding the test. Level I PSG was performed as per the American Association of Sleep Medicine (AASM) guidelines, during the daytime from 12 PM to 4 PM in the sleep lab under the supervision of an experienced sleep technician [18]. The patients were asked to sleep less on the previous night compared to other days. All PSG studies included the following: electroencephalography (six probes and two ground leads, electrooculography (bilateral), chin electromyography, oronasal thermistor, nasal pressure, piezoelectric snore, pulse oximetry, electrocardiography, and respiratory inductance plethysmography for chest and abdominal movements. At least 2 hours of PSG recording were required for inclusion for further analysis. PSG was scored manually by a sleep specialist using an Alice PSG system and Sleepware software (Koninklijke Philips N.V., Amsterdam, Netherlands). The respiratory events were scored as per the AASM guidelines. Apneas and hypopneas were identified on oronasal thermistor and nasal pressure tracings, respectively. OSA was diagnosed when the AHI was at least 5/hour. If the daytime PSG yielded a negative result (AHI <5/hour), the sleep efficiency was <30%, or the result was inconclusive, a conventional overnight PSG was performed to reach a diagnosis. This overnight PSG was done within 2 weeks of the daytime test.

Statistical analysis was done using IBM SPSS Statistics for Windows, version 21 (IBM Corp., Armonk, NY, USA). A p-value of ≤0.05 was considered the cut-off for statistical significance. Sensitivity and negative predictive value (NPV) were calculated using the standard formulae. The sample size was calculated using the formula for diagnostic tests [19]. The margin of error and power were taken as 5% and 20%, respectively. Based on preliminary results from an internal review of 19 patients, a sensitivity of 85% was applied. Using these values, the sample size was a minimum of 87.

Results

The study flow is presented in Figure 1. A total of 162 patients were evaluated for PSG during the study period. After exclusion, 105 patients underwent daytime PSG. Their demographic, sleep-historical, and PSG parameters are presented in Table 1. The study population had a mean age of 53.03±11.93 years and had 42 (40%) women. The mean body mass index (BMI) was 33.58±5.42 kg/m^2. Obesity (BMI≥30 kg/m^2) was noted in 83 (79.05%) individuals.

The mean STOP-Bang score was 5.4±1.48. Out of 105 individuals, 97 (92.38%) had a positive score of >3. The mean ESS score in the study was 17.3±5.27. Excessive daytime sleepiness with an ESS score of ≥11 was noted in 93 (88.57%) patients. The mean PSAP score was 5.48±1.57, and 94 individuals (89.52%) had a positive score of ≥4. Among sleep related symptoms, the most reported was loud snoring (n=97; 92.38%), followed by excessive daytime sleepiness (n=91; 86.67%), lethargy (n=88; 83.81%), unrefreshing sleep (n=73; 69.5%), and dryness of throat on waking up (n=63; 60%). Nocturnal awakening, *i.e*., waking with gasping, choking, or breath holding, was noted in 61 (58.1%) patients. Comorbid insomnia (n=21; 21%), restless leg syndrome (n=27; 25.71%), and psychiatric disorders like depression (n=23; 21.9%) were also commonly noted.

Out of 105 individuals undergoing daytime PSG, 86 (81.9%) had an AHI≥5/hr and thus were diagnosed as OSA on daytime PSG (true positives). The remaining 19 (18.1%) had an AHI of <5/hr. These participants were advised to undergo a conventional nighttime PSG for validation of the result. Out of these 19 participants, 7 refused the nighttime PSG, citing reasons attributed to travel difficulties during the COVID-19 pandemic or a lower severity of OSA symptoms. The remaining 12 patients underwent the conventional nighttime PSG. 10 out of these 12 individuals were diagnosed with OSA (false negatives). In the remaining 2 individuals, OSA was ruled out during nighttime PSG. These 2 individuals were true negatives who had been correctly identified by the daytime PSG and verified by nighttime PSG. After exclusion of 7 patients out of 105, who had refused the nighttime study, the tests of diagnostic evaluation were applied among 98 patients. The sensitivity of daytime PSG to diagnose OSA was noted as 89.58% [95% confidence interval (CI): 81.68 to 94.89%], and the overall diagnostic accuracy for the study was 89.80% (95% CI: 82.03 to 95%). The NPV was noted as 16.67% (95% CI: 10.01 to 26.45%). The negative likelihood ratio was 0.1 (95% CI: 0.06 to 0.19).

A comparison of relevant parameters among 86 true positives *vs.* 10 false negatives is presented in Table 2. They had comparable age, sex ratio, and BMI. The mean self-reported sleep durations were not significantly different in the two groups (5.88±1.09 *vs.* 6.2±1.48 hrs/night, p=0.4). The prevalence of loud snoring was greater among true positives (95.35%) than false negatives (80%), however, the difference was not statistically significant (p=0.06). Early morning headache was more commonly reported by false negatives than by true positives (90% *vs*. 52.32%; p=0.03). Among other historical parameters, there were no significant differences between the two groups. The prevalence of modified Mallampati classes 3 or 4 was significantly greater (p=0.03) among true positives (80.23%) compared to false negatives (50%). There were no significant differences in the mean STOP-Bang or ESS scores or the prevalence of positive scores between the groups. Only the mean PSAP score was significantly greater among true positives (5.71±1.46) than false negatives (4.7±1.57, p=0.04).

The PSG parameters in daytime PSG of true positives were

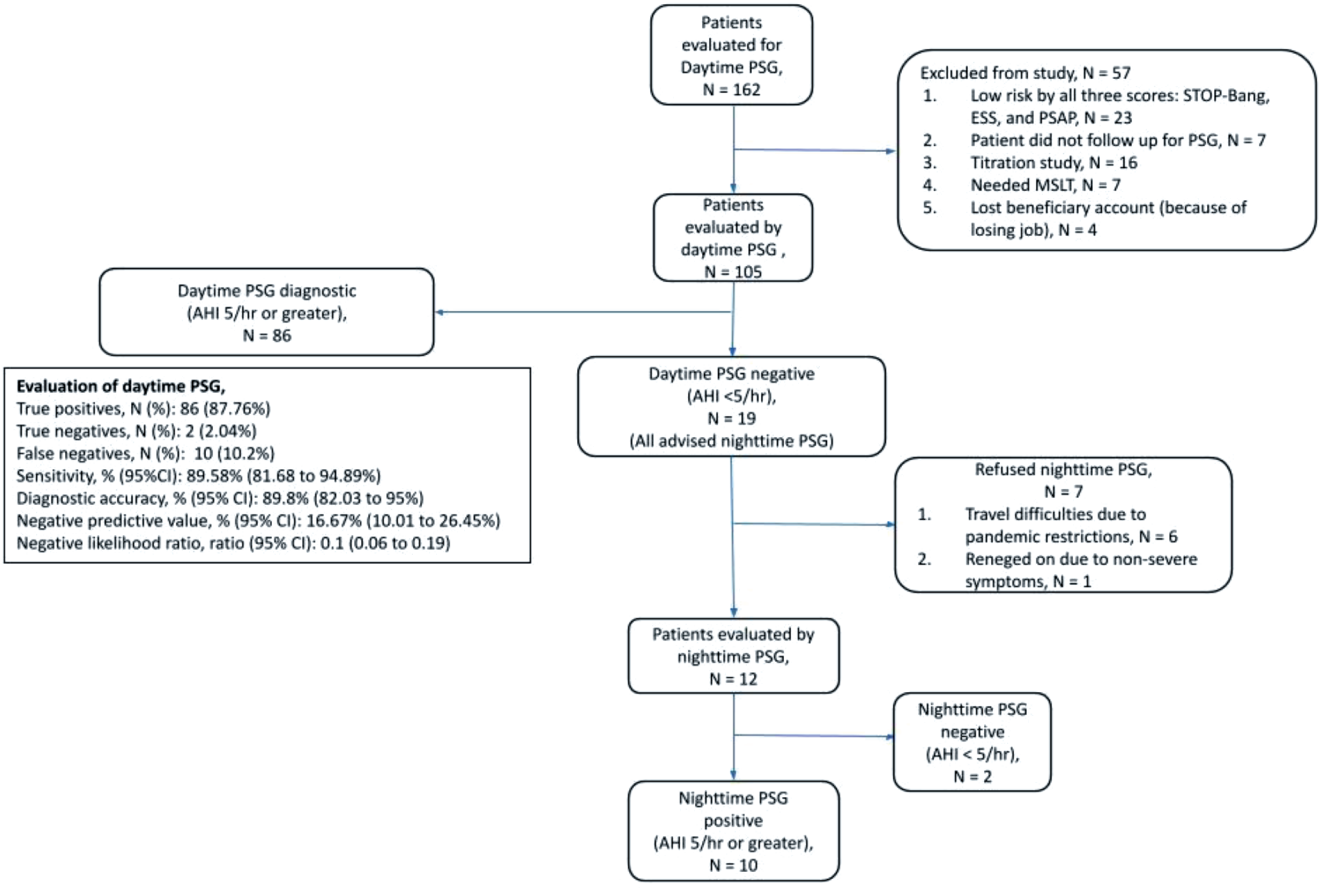

Figure 1. Study flow. AHI, apnea hypopnea index; 95% CI, 95% confidence interval; ESS, Epworth sleepiness scale; MSLT, multiple sleep latency test; PSAP, perioperative sleep apnea probability; PSG, polysomnography.

compared to nighttime PSG of false negatives. The mean AHI was significantly greater (p=0.05) among true positives (42.4±27.37) than false negatives (24.96±19.76). Also, the prevalence of mild OSA was significantly greater among false negatives than true positives (50% *vs.* 15.21%; p=0.01). The prevalence of moderate and severe OSA was greater among true positives than false negatives; however, the differences were not statistically significant. The mean sleep efficiency was similar between the two groups (65.7±25.05% *vs.* 64.24±18.48%; p=0.86). The mean sleep latency was significantly lower among true positives than false negatives (13.41±18.24 minutes *vs.* 30±40.39 minutes; p=0.02). On analysis of the sleep architecture, there was a greater number of true positives who had attained deep sleep, reaching deep (N3) sleep stage, compared to false negatives (84.88% *vs.* 60%, p=0.05). However, there was no difference in rapid eye movement (REM) sleep. Also, we analyzed the daytime PSG of the 10 patients who were false negatives. They had a mean AHI of 3/hr with a mean sleep efficiency of 55.5%. Their mean sleep latency was 16.78 minutes. Analyzing sleep architecture, N3 sleep was noted in 80% and REM sleep in 40% of patients.

Discussion

This study evaluated the utility of daytime PSG for diagnosing OSA in consecutive high-risk individuals, under the health and social support benefits scheme of India. The sensitivity of daytime PSG in diagnosing OSA was found to be 89.58%, with an overall diagnostic accuracy of 89.8% for the study participants. In these individuals, performing PSG during the daytime eliminates the need for an overnight stay and the concerns associated with it. This helps in reducing waiting times for patients queuing up for PSG testing by essentially half, since at least one daytime and one nighttime study can be performed on a single date. It is especially important for high patient-load centers in resource-limited settings, such as ours. In case of a negative daytime PSG result, verification can be sought by performing a nighttime study.

We took the specificity of daytime PSG to be equivalent to nighttime PSG. All individuals detected with OSA on daytime PSG were counted as true positives. This was based on the results of earlier studies. Miyata *et al.* (2007) evaluated 108 patients with suspected sleep disordered breathing. [9] They performed daytime and nighttime PSGs for all 108 individuals and found the specificity of daytime PSG to be 100%. They reported 81.0% sensitivity and 83.5% accuracy of daytime PSG. They evaluated the utility of daytime PSG for continuous positive airway pressure titration compared to nighttime PSG and found no significant difference [9]. In a study by Mahakit *et al.* (2012) comparing daytime PSG to nighttime PSG, the sensitivity, specificity, positive predictive value, and NPV were noted as 92%, 91.3%, 92%, and 91.3%, respectively [10]. Bosschieter *et al.* utilized daytime PSG to perform titration of upper airway stimulation therapy as an alternative to conventional overnight PSG. They found that 94% of patients had a positive experience with the daytime study, and titration was successful in evaluating the final therapeutic settings in 84% of patients despite an overall lower sleep time [11]. The positive results of daytime PSG were also supported by studies conducted in the 20th century [20,21]. Additional reasons also prompted us to not pursue a conventional nighttime PSG in patients diagnosed on the daytime test. Firstly, the scenario where an individual has OSA during daytime sleep and not nighttime sleep carries little biological plausibility. In the presence of symptoms, a positive daytime PSG necessitates treatment for OSA. Secondly, individuals were apprehensive about

Table 1. Descriptive parameters of study participants.

Descriptive parameter	Value
Demographic characteristics	
Age, years (mean, std dev)	53.03, 11.93
Age, years (median, Q1-Q3)	53, 45-60
Gender, N (Female:male)	42:63
Shift worker, N (%)	8 (7.62)
Sleep history	
Self-reported sleep duration, hours/night (mean, std dev)	5.91, 1.11
Loud snoring, N (%)	97 (92.38)
Wake-up due to own snoring, N (%)	59 (56.19)
Witnessed apnea, N (%)	59 (56.19)
Waking with gasping, choking, or breath holding N (%)	61 (58.1)
Nocturia, N (%)	53 (50.48)
Fragmented sleep, N (%)	48 (45.71)
Unrefreshing sleep, N (%)	73 (69.52)
Early morning headache, N (%)	55 (52.38)
Dryness of throat on waking up, N (%)	63 (60)
Insomnia, N (%)	21 (20)
Restless leg syndrome, N (%)	27 (25.71)
Excessive daytime sleepiness, N (%)	91 (86.67)
Lethargy, N (%)	88 (83.81)
Cognitive deficit, N (%)	36 (34.28)
Psychiatric symptoms, N (%)	23 (21.90)
Clinical characteristics	
BMI, kg/m^2 (mean, std dev)	33.58, 5.42
Class I obesity (BMI 30-34.9)	32 (30.48)
Class II obesity (BMI 35-39.9)	31 (29.52)
Class III obesity (BMI≥40)	10 (9.52)
Neck circumference, cm (mean, std dev)	41.35, 3.42
Neck circumference >41 cm, N (%)	62 (59.05)
Modified Mallampati class 3 or 4, N (%)	79 (75.24)
Waist circumference, cm (mean, std dev)	102.05, 9.42
Pre-test probability scores	
STOP-Bang score, (mean, std dev)	5.4, 1.48
STOP-Bang score ≥3, N (%)	102 (97.14)
STOP-Bang score ≥4, N (%)	97 (92.38)
STOP-Bang score ≥5, N (%)	72 (68.57)
STOP-Bang score ≥6, N (%)	55 (52.38)
ESS score, (mean, std dev)	17.3, 5.27
ESS score 0-10, N (%)	12 (11.43)
ESS score 11-14, N (%)	18 (17.14)
ESS score 15-17, N (%)	12 (11.43)
ESS score 18-24, N (%)	63 (60)
PSAP score, (mean, std dev)	5.48, 1.57
PSAP score ≥4, N (%)	94 (89.52)
Polysomnographic parameters	
AHI, /hr (mean, std dev)	35.01, 28.87
AHI, /hr (median, Q1-Q3)	27.5 (10.9-54)
AHI <5/hr, N (%)	19 (18.1)
OSA (AHI >5)	86 (81.9)
Mild OSA: AHI 5-<15/hr, N (%)	14 (13.33)
Moderate OSA: AHI 15-<30/hr, N (%)	23 (21.9)
Severe OSA: AHI ≥30/hr, N (%)	49 (46.67)
Sleep efficiency, % (mean, std dev)	64.61, 25.81
Sleep latency, min (mean, std dev)	13.31, 17.89
Sleep latency, min (median, Q1-Q3)	5 (0.5-19.5)
N1 or N2 established, N (%)	104 (98.11)
N3 established, N (%)	90 (84.9)
R established, N (%)	31 (29.24)

AHI, apnea hypopnea index; BMI, body mass index; ESS, Epworth sleepiness scale; N1, N2, N3, non rapid eye movement sleep, phases 1-3; R, rapid eye movement sleep phase; OSA, obstructive sleep apnea; PSAP, perioperative sleep apnea score; Q1-Q3, quartile range (1st to 3rd); Std dev, standard deviation.

an overnight stay at the hospital during the COVID-19 pandemic. The frequent time restrictions placed during the pandemic made access during evening hours difficult. Thirdly, multiple PSG sessions add to the burden in terms of resource utilization.

The total sleep time during daytime PSG plays a crucial role in its results. Van Keimpema *et al.* (1992) found the specificity of daytime PSG to be 88% but a relatively low sensitivity of 66% [12]. They had recorded only one hour of sleep during daytime PSG, which could have resulted in low sensitivity. Mahakit *et al.* recorded 2 hours of sleep time on daytime PSG after inducing sleep using oral midazolam, which resulted in a sensitivity and specificity of >90% [10]. Miyata *et al.* used 2 hours of total sleep time on daytime PSG with natural sleep and found a specificity of 100% [9]. We conducted daytime PSGs from 12 PM to 4 PM (4 hours); hence, the probability of missing the diagnosis of OSA in our study is very low. Further, data were included for analysis if at least 2 hours of sleep

Table 2. Comparison of daytime PSG and nighttime PSG in the study participants

			p	Confidence interval or Chi-square
A. Demographic and clinical parameters: daytime PSG of true positives *vs.* nighttime PSG of false negatives				
	Daytime PSG	**Nighttime PSG**		
A.1 Demographic parameters				
N	86	10		
Age, years (mean, std dev)	53.95, 11.21	53.4, 14.23	0.89	-7.1010 to 8.2010
Age, years (median, Q1-Q3)	54.5, 46.25-60.75	56, 41.5-63.75		
Women, N (%)	31 (36.05)	6 (60)	0.14	chi sq 2.17
Shift worker, N (%)	7 (8.14)	0 (0)	0.35	0.88
A.2 Sleep history				
Self-reported sleep duration, hours/night (mean, std dev)	5.88, 1.09	6.2, 1.48	0.4	-1.0717 to 0.4317
Loud snoring, N (%)	82 (95.35)	8 (80)	0.06	3.6
Wake-up due to own snoring, N (%)	47 (54.65)	8 (80)	0.12	2.35
Witnessed apnea, N (%)	49 (56.98)	8 (80)	0.16	1.97
Waking with gasping, choking, or breath holding, N (%)	51 (59.3)	8 (80)	0.2	1.62
Nocturia, N (%)	46 (53.49)	3 (30)	0.16	1.98
Fragmented sleep, N (%)	39 (45.35)	6 (60)	0.38	0.77
Unrefreshing sleep, N (%)	60 (69.77)	8 (80)	0.5	0.45
Early morning headache, N (%)	45 (52.32)	9 (90)	0.03	5.17
Dryness of throat on waking up, N (%)	53 (61.63)	8 (80)	0.25	1.3
Insomnia, N (%)	16 (18.6)	4 (40)	0.11	2.49
Restless leg syndrome, N (%)	24 (27.91)	3 (30)	0.89	0.02
Excessive daytime sleepiness, N (%)	74 (86.05)	10 (100)	0.21	1.6
Lethargy, N (%)	73 (84.88)	9 (90)	0.66	0.19
Cognitive deficit, N (%)	27 (31.4)	6 (60)	0.07	3.25
Psychiatric symptoms, N (%)	19 (22.09)	4 (40)	0.21	1.58
A3. Clinical parameters				
BMI, kg/m^2 (mean, std dev)	33.78, 5.12	32.87, 4.24	0.59	-2.44 to 4.26
Class I obesity (BMI 30-34.9)	25 (29.07)	3 (30)	0.95	0.004
Class II obesity (BMI 35-39.9)	23 (26.74)	4 (40)	0.38	0.78
Class III obesity (BMI ≥40)	10 (11.63)	0 (0)	0.25	1.3
Neck circumference, cm (mean, std dev)	41.65, 3.09	40.6, 2.01	0.3	-0.94 to 3.04
Neck circumference >41 cm, N (%)	54 (62.79)	4 (40)	0.16	1.95
Modified Mallampati class 3 or 4, N (%)	69 (80.23)	5 (50)	0.03	4.64
Waist circumference, cm (mean, std dev)	102.2, 9.13	105.1, 6.97	0.33	-8.83 to 3.03
A4. Pre-test probability scores				
STOP BANG score, (mean, std dev)	5.57, 1.41	5.2, 1.55	0.44	-0.57 to 1.31
STOP BANG score ≥3, N (%)	85 (98.84)	9 (90)	0.06	3.43
STOP BANG score ≥4, N (%)	81 (94.19)	9 (90)	0.6	0.27
STOP BANG score ≥5, N (%)	62 (72.09)	7 (70)	0.89	0.02
STOP BANG score ≥6, N (%)	49 (56.98)	5 (50)	0.67	0.18
ESS score, (mean, std dev)	17.66, 5.46	17, 3.33	0.71	-2.85 to 4.17
ESS score 0-10, N (%)	10 (11.63)	0 (0)	0.25	1.3
ESS score 11-14, N (%)	13 (15.12)	3 (30)	0.23	1.43
ESS score 15-17, N (%)	7 (8.14)	2 (20)	0.22	1.48
ESS score 18-24, N (%)	56 (65.17)	5 (50)	0.35	0.88
PSAP score, (mean std dev)	5.71, 1.46	4.7, 1.57	0.04	0.03 to 1.98
PSAP score ≥4, N (%)	80 (93.02)	8 (80)	0.16	1.99

To be continued on next page

Table 2. Continued from previous page.

			p	Confidence interval or Chi-square
B. Polysomnography parameters: daytime PSG of true positives *vs.* nighttime PSG of false negatives				
	Daytime PSG of true positives	**Nighttime PSG of false negatives**		
N	86	10		
AHI, /hr (mean, std dev)	42.4, 27.37	24.96, 19.76	0.05	-0.3 to 35.18
AHI, /hr (median, Q1-Q3)	32.75 (20.85-63.52)	15.65 (9.55-36.55)		
AHI <5/hr, N (%)	0 (0)	0 (0%)	1	0
OSA: AHI >5	86 (100)	10 (100)	1	0
Mild OSA: AHI 5-<15/hr, N (%)	13 (15.12)	5 (50)	0.01	7.16
Moderate OSA: AHI 15-<30/hr, N (%)	24 (27.91)	1 (10)	0.22	1.49
Severe OSA: AHI ≥30/hr, N (%)	49 (56.98)	4 (40)	0.31	1.04
Sleep efficiency, % (mean, std dev)	65.7, 25.05	64.24, 18.48	0.86	-14.79 to 17.11
Sleep latency, min (mean, std dev)	13.41, 18.24	30, 40.39	0.02	-30.77 to -2.41
Sleep latency, min (median, Q1-Q3)	4.75 (0.5-19.5)	10.5 (4.5-44)		
N1 or N2 established, N (%)	86 (100)	10 (100)	1	0
N3 established, N (%)	73 (84.88)	6 (60)	0.05	3.81
R established, N (%)	25 (29.07)	3 (30)	0.95	0.004
C. Polysomnography parameters: daytime PSG of true positives *vs.* daytime PSG of false negatives				
	Daytime PSG of true positives	**Daytime PSG of false negatives**		
N	86	10		
AHI, /hr (mean, std dev)	42.4, 27.37	3, 1.64	<0.001	22.13 to 56.67
AHI, /hr (median, Q1-Q3)	32.75 (20.85-63.52)	3.55 (1.72-4.15)		
AHI <5/hr, N (%)	0 (0)	10 (100%)	0	1
OSA: AHI >5	86 (100)	0 (0)	0	1
Mild OSA: AHI 5-<15/hr, N (%)	13 (15.12)	0 (0)	0	1
Moderate OSA: AHI 15-<30/hr, N (%)	24 (27.91)	0 (0)	0	1
Severe OSA: AHI ≥30/hr, N (%)	49 (56.98)	0 (0)	0	1
Sleep efficiency, % (mean, std dev)	65.7, 25.05	55.5, 35.04	0.24	-7.16 to 27.56
Sleep latency, min (mean, std dev)	13.41, 18.24	16.78, 19.68	0.58	-15.56 to 8.82
Sleep latency, min (median, Q1-Q3)	4.75 (0.5-19.5)	10 (0.5-29.5)		
N1 or N2 established, N (%)	86 (100)	9 (90)	0.003	8.69
N3 established, N (%)	73 (84.88)	8 (80)	0.69	0.16
R established, N (%)	25 (29.07)	4 (40)	0.48	0.51

AHI, apnea hypopnea index; BMI, body mass index; ESS, Epworth sleepiness scale; N1, N2, N3, non-rapid eye movement sleep, phases 1-3; R, rapid eye movement sleep phase; OSA, obstructive sleep apnea; PSAP, perioperative sleep apnea score; PSG, polysomnography; Q1-Q3, quartile range (1st to 3rd); Std dev, standard deviation.

were recorded, thus adding another layer of confidence in the quality of daytime PSG. Comparing individuals who were diagnosed with OSA on daytime PSG (true positives) to those who were not diagnosed and required a nighttime PSG (false negatives), the true positives had a significantly greater AHI and lower sleep latency. False negatives were more frequently mild OSA, compared to true positives. This suggests that patients with mild OSA symptoms or higher sleep latency are less likely to be diagnosed using daytime PSG. At 16.67%, we found the NPV in our study to be low. This would suggest that a negative daytime PSG result in a suspected patient should be re-evaluated by a conventional overnight PSG to confirm or rule out OSA. The sleep efficiency was similar in both groups. This has also been found in previously published evidence [9]. The tendency of an individual to fall asleep during the day (daytime sleepiness), as assessed by the ESS score, also did not differ significantly between the two groups in our study.

One potential concern of performing PSG during the day as opposed to at night is that deep sleep may not be achieved well during the day. Many contributory factors have been suggested for why daytime sleep differs from nighttime sleep [22]. In the current study, the sleep architecture was analyzed during daytime PSG. We found fewer individuals reached N3 compared to early sleep (N1 or N2) during daytime PSG. The difference in REM sleep was not significant, probably because only about 30% of patients could achieve REM sleep in each group. The absence of REM sleep could be explained by the first-night effect [23,24]. This phenomenon consists of a lower sleep efficiency, a lower amount of REM sleep, and a longer REM latency on the first night in the sleep center [25,26]. This could also be expected during daytime sleep in the sleep lab [20,21]. Further, individuals with false negative results on daytime PSG were found to have a lower frequency of N3 (80% of individuals) or REM (40% of individuals) sleep. We, therefore, suggest a follow-up nighttime PSG to evaluate individuals who fail to attain REM or N3 sleep on daytime PSG.

There are some limitations to the current study. We could not perform nighttime PSG for all the individuals who could have validated our results of 100% specificity of daytime PSG. Further, among the 19 patients with a non-yielding daytime PSG, 7 refused a nighttime PSG. The exact cause of negative daytime PSG results, hence, could not be ascertained. They probably had no or

mild OSA that did not significantly affect their daily life and therefore refused a repeat PSG. At the same time, however, this may also suggest that a daytime PSG is more patient-friendly compared to a nighttime study.

Conclusions

The daytime PSG has a sensitivity of 89.58% and diagnostic accuracy of 89.80% for diagnosing OSA. The likelihood of a negative result is greater in mild OSA cases. At high patient-load centers, daytime PSG can be used in carefully selected individuals with a high pre-test probability. This can reduce PSG wait times and the additional cost of nighttime sleep technician attendance. We therefore propose using daytime PSG as an acceptable and more patient-friendly alternative to nighttime PSG for OSA at sleep centers with high patient load and long wait times. If the result of daytime PSG is negative, a follow-up conventional nighttime PSG is suggested.

References

1. Lyons MM, Bhatt NY, Pack AI, et al. Global burden of sleep-disordered breathing and its implications. Respirology 2020;25:690-702.
2. Suri TM, Ghosh T, Mittal S, et al. Systematic review and meta-analysis of the prevalence of obstructive sleep apnea in Indian adults. Sleep Med Rev 2023;71:101829.
3. Sharma SK, Katoch VM, Mohan A, et al. Consensus and evidence-based Indian initiative on obstructive sleep apnea guidelines 2014 (first edition). Lung India 2015;32:422-34.
4. Rosen IM, Kirsch DB, Carden KA, et al. Clinical use of a home sleep apnea test: an updated American Academy of Sleep Medicine position statement. J Clin Sleep Med 2018;14:2075-7.
5. Jensen MH, Dalgaard F, Laub RR, et al. Protocol for detecting unrecognized sleep apnea in patients with atrial fibrillation by a home-monitoring device: the DAN-APNO study. BMC Cardiovasc Disord 2022;22:6.
6. Gupta N, Ish P, Kumar R, et al. Evaluation of the clinical profile, laboratory parameters and outcome of two hundred COVID-19 patients from a tertiary centre in India. Monaldi Arch Chest Dis 2020;90.
7. Ministry of Health and Family Welfare, Government of India. Enabling delivery of essential health services during the COVID 19 outbreak: guidance note. Available from: https://www.mohfw.gov.in/pdf/EssentialservicesduringCOVID19updated0411201.pdf. Accessed on: 24/09/2023.
8. World Health Organization. Maintaining essential health services: operational guidance for the COVID-19 context. 2020. Available from: https://www.who.int/publications/i/item/WHO-2019-nCoV-essential_health_services-2020.2. Last accessed on: 24/09/2023.
9. Miyata S, Noda A, Nakata S, et al. Daytime polysomnography for early diagnosis and treatment of patients with suspected sleep-disordered breathing. Sleep Breath 2007;11:109-15.
10. Mahakit P. A comparative study of two-hour daytime and overnight polysomnography in high risk snorers. J Med Assoc Thai 2012;95:S17-22.
11. Bosschieter PFN, Schoustra E, de Vries N, et al. Daytime polysomnography to perform titration for upper airway stimulation in patients with obstructive sleep apnea. Sleep Breath 2022;26:707-15.
12. Van Keimpema AR, Rutgers SR, Strijers RL. The value of one hour daytime sleep recording in the diagnosis of the sleep apnoea syndrome. J Sleep Res 1993;2:257-9.
13. Aguirregomoscorta Urquijo JI, Menéndez Gastan I, Aparicio Abendaño S, et al. Nap polysomnography: sufficient grounds for initiating CPAP treatment?. Arch Bronconeumol 2001;37:302-6. [Article in Spanish].
14. Sergi M, Rizzi M, Greco M, et al. Validity of diurnal sleep recording performed by an ambulatory device in the diagnosis of obstructive sleep apnoea. Respir Med 1998;92:216-20.
15. Boynton G, Vahabzadeh A, Hammoud S, et al. Validation of the STOP-BANG questionnaire among patients referred for suspected obstructive sleep apnea. J Sleep Disord Treat Care 2013;2:10.
16. Feltner C, Wallace IF, Aymes S, et al. Screening for obstructive sleep apnea in adults: updated evidence report and systematic review for the US preventive services task force. JAMA 2022;328:1951-71.
17. Mahismita P, Chandra OU, Dipti G, et al. Utility of combination of sleep questionnaires in predicting obstructive sleep apnea and its correlation with polysomnography. Indian J Sleep Med 2019;14:61-6.
18. Kapur VK, Auckley DH, Chowdhuri S, et al. Clinical practice guideline for diagnostic testing for adult obstructive sleep apnea: an American Academy of Sleep Medicine Clinical practice guideline. J Clin Sleep Med 2017;13:479-504.
19. Akoglu H. User's guide to sample size estimation in diagnostic accuracy studies. Turk J Emerg Med 2022;22:177-85.
20. Mizuma H, Sonnenschein W, Meier-Ewert K. Diagnostic use of daytime polysomnography versus nocturnal polysomnography in sleep apnea syndrome. Psychiatry Clin Neurosci 1996;50:211-6.
21. Haraldsson PO, Carenfelt C, Knutsson E, et al. Preliminary report: validity of symptom analysis and daytime polysomnography in diagnosis of sleep apnea. Sleep 1992;15:261-3.
22. Yakar F, Yakar A, Sezer M, et al. Role of daytime polysomnography in the diagnosis of sleep apnea syndrome. Tuberk Toraks 2015;63:78-85.
23. Agnew Jr HW, Webb WB, Williams RL. The first night effect: an EEG study of sleep. Psychophysiology 1966;2:263-6.
24. Browman CP, Cartwright RD. The first-night effect on sleep and dreams. Biol Psychiatry 1980;15:809-12.
25. Curcia G, Ferrara M, Ciersiaooi A, et al. Paradoxes of the first-night effect: a quantitative analysis of antero-posterior EEG topography. Clin Neurophysiol 2004;115:1178-88.
26. Toussaint M, Luthringer R, Schaltenbrand N, et al. First-night effect in normal subjects and psychiatric inpatients. Sleep 1995;18:463-9.