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Factors associated with respiratory disturbance index higher than apnea-hypopnea index in patients with obstructive sleep apnea

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Abstract. Polysomnography, used for diagnosing obstructive sleep apnea (OSA), is commonly available with a home sleep apnea test (HSAT) and in-laboratory polysomnography. In-laboratory polysomnography, the gold standard test, is expensive and has a long waitlist, whereas HSATs are inexpensive and sensitive but may not adequately detect respiratory effort-related arousal (RERA), the presence of which results in a higher respiratory disturbance index (RDI) than the apnea-hypopnea index (AHI) and may indicate more severe OSA. In certain patients, identifying factors associated with a higher RDI than AHI may decrease the need for full polysomnography. The present retrospective analytical study of adult patients with OSA diagnosed by in-laboratory polysomnography aimed to evaluate factors associated with a higher RDI than AHI. Factors associated with a higher RDI than AHI were computed via multivariable logistic regression analysis. Of 72 patients with OSA, 27 (37.50%) had an RDI higher than AHI. There were five factors in the predictive model for RDI higher than AHI: Age, sex, hypertension, diabetes, body mass index (BMI) and snoring, tired, observed apnea, high blood pressure, body mass index, age, neck circumference, and gender score. Only BMI was independently associated with a higher RDI than AHI [adjusted odds ratio, 1.10 (95% confidence interval: 1.01, 1.19)] and a BMI of 26.03 kg/m^2 had a sensitivity of 81.48% and a specificity of 33.33% in detecting higher RDI than AHI. The receiver operating characteristic (ROC) curve of BMI for RDI higher than AHI was 60.66% (95% confidence interval: 46.53%, 74.78%). Although the area under the ROC curve had modest predictive ability, patients with suspected OSA with a BMI of 26.03 kg/m^2 may require in-laboratory polysomnography, whereas other patients may be tested via HSAT.

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Introduction

Obstructive sleep apnea (OSA) is estimated to affect 83.7 million adult patients in the United States (1). OSA is associated with several diseases, such as hypertension, coronary artery disease and depression, as well as economic burden (2), including a loss in productivity of US $86.9 billion annually (2). Studies have shown that OSA severity may be associated with coronary artery disease, including coronary calcification or atherosclerosis (3,4). In one study, patients with OSA and an apnea-hypopnea index (AHI) of ≥15 events/h demonstrated significantly higher N-terminal pro B-type natriuretic peptide (275.8 vs. 131.9 pg/ml) and high-sensitivity cardiac troponin T levels (0.011 vs. 0.008 ng/ml) than patients with an AHI <15 events/h (3).

The American Academy of Sleep Medicine recommends either in-laboratory polysomnography or a home sleep apnea test (HSAT) to diagnose OSA (5). Although HSATs outperform in-laboratory polysomnography in terms of cost, patient satisfaction and wait times (6), they have some limitations, particularly regarding scores for respiratory effort-related arousal (RERA). RERA is defined as a period encompassing a sequence of breaths of ≥10 sec, with a flattening of the inspiratory portion of the nasal pressure followed by arousal, that does not meet criteria for apnea or hypopnea (7,8). Unlike apnea or hypopnea events, RERA events begin with a partial narrowing or functional instability of the upper airway leading to progressive inspiratory effort to maintain adequate ventilation. This increasing effort results in elevated negative intrathoracic pressure during inspiration, a condition known as flow limitation. Cortical arousal in the brain restores muscle tone of the upper airway to open the passage (5,8). In patients with OSA, RERA is associated with prevalent hypertension with a sensitivity of 75% and a specificity of 83% (9).

High RERA score may result in more severe OSA or a higher respiratory disturbance index (RDI). Because OSA severity may be misclassified when relying on HSATs alone, undertreatment with a continuous positive airway pressure machine (CPAP) may occur, which can result in early cardiovascular diseases and/or other consequences (10). For patients who tend to have an RDI higher than AHI, in-laboratory polysomnography may be preferred, whereas patients with an RDI equal to AHI may proceed with HSATs to save diagnostic costs. However, data remain limited about the phenotypes of

Table I. Clinical features of patients with obstructive sleep apnea categorized by relative RDI and AHI.

Characteristic	RDI=AHI (n=45)	RDI>AHI (n=27)	P-value
Median age, years (interquartile range)	49 (35-60)	53 (35-61)	0.780
Male sex (%)	14 (31.11)	12 (44.44)	0.314
Comorbidity (%)			
Hypertension	19 (42.22)	7 (25.93)	0.209
Diabetes	11 (24.44)	4 (14.81)	0.384
Obesity	27 (60.00)	22 (81.48)	0.071
Dyslipidemia	17 (37.78)	11 (40.74)	0.808
Allergic rhinitis	12 (26.67)	5 (18.52)	0.569
Asthma	4 (8.89)	0 (0.00)	0.290
Hypothyroidism	1 (2.22)	1 (3.70)	0.999
Chronic kidney disease	1 (2.22)	2 (7.41)	0.552

RDI, respiratory disturbance index; AHI, apnea-hypopnea index.

Table II. Physical characteristics features of patients with obstructive sleep apnea categorized by relative RDI and AHI.

Characteristic	RDI=AHI (n=45)	RDI>AHI (n=27)	P-value
Weight, kg	70.00 (64.00-89.00)	85.00 (70.00-103.00)	0.053
Height, cm	159.00 (155.00-165.00)	163.00 (157.00-171.00)	0.136
Body mass index, kg/m^2	28.04 (24.68-32.05)	30.04 (26.04-38.51)	0.132
Neck circumference, cm	38.50 (35.00-40.50)	40.00 (38.00-42.50)	0.244
Systolic blood pressure, mmHg	133.00 (125.00-138.00)	131.00 (126.00-140.00)	0.563
Diastolic blood pressure, mmHg	77.00 (72.00-90.00)	80.00 (73.00-84.00)	0.834
STOP-BANG score	4.00 (3.00-5.00)	4.00 (3.00-5.00)	0.693

All data are presented as median (interquartile range). RDI, respiratory disturbance index; AHI, apnea-hypopnea index; STOP-BANG, snoring, tired, observed apnea, high blood pressure, body mass index, age, neck circumference and gender.

patients with OSA who have RDIs higher than AHIs (11). Therefore, the present study aimed to evaluate whether any clinical factors predict RDIs higher than AHIs in patients with OSA.

Materials and methods

Study design and population. From October 2024 to June 2025, a retrospective analytical study was performed at Khon Kaen University Hospital in Khon Kaen, Thailand. Inclusion criteria were patients aged ≥18 years diagnosed with OSA based on an AHI of ≥5 times/h by in-laboratory polysomnography, and both AHI and RDI were scored. Patients who were pregnant or diagnosed with OSA using HSATs were excluded. The study protocol was approved by Khon Kaen University Ethics Committee in Human Research (approval no. HE641504).

The clinical features and polysomnography results of eligible patients were recorded from medical records. Clinical features included age, sex, comorbidities and physical signs [weight, height, body mass index (BMI), neck circumference, blood pressure and snoring, tired, observed apnea, high blood pressure, body mass index, age, neck circumference, and gender (STOP-BANG) score (12); polysomnography results included AHI, RDI and lowest oxygen saturation. Patients were categorized into two groups: RDI=AHI and RDI>AHI group. RERA was scored using the American Academy of Sleep Medicine updated 2007 manual for scoring sleep and associated events (13). Polysomnography was performed by a sleep physician who was not blinded to the participant clinical features.

Sample size calculation. It was predicted that 15% of patients with OSA would have an RDI higher than AHI. With a confidence interval of 90% and a margin of error of 7%, the required sample size was 71.

Statistical analysis. Descriptive statistics were used to compare the clinical features and polysomnography of both groups. Numerical variables are presented as median (interquartile range), while categorical variables were reported as number (percentage). Factors associated with an RDI higher than AHI were computed using logistic regression analysis and the P-values of studied variables were calculated using univariate logistic regression analysis. Factors with P<0.20

Table III. Polysomnography results of patients with obstructive sleep apnea categorized by relative RDI and AHI.

Characteristic	RDI=AHI (n=45)	RDI>AHI (n=27)	P-value
Apnea-hypopnea index, times/h	27.3 (15.2-44.5)	40.7 (25.1-61.1)	0.077
Respiratory disturbance index, times/h	27.3 (15.2-44.5)	53.6 (33.7-67.8)	0.006
Lowest oxygen saturation, %	86 (80-89)	84 (81-88)	0.828

All data are presented as median (interquartile range). RDI, respiratory disturbance index; AHI, apnea-hypopnea index.

Table IV. Predictors of presence of respiratory disturbance index higher than apnea-hypopnea index in patients with obstructive sleep apnea.

Predictor	Unadjusted odds ratio (95% confidence interval)	Adjusted odds ratio (95% confidence interval)
Age	1.00 (0.72, 1.04); 0.785	1.03 (0.99, 1.07); 0.125
Male sex	0.56 (0.21, 1.51); 0.256	0.45 (0.15, 1.32); 0.147
Hypertension	0.48 (0.17, 1.36); 0.167	0.45 (0.14, 1.42); 0.173
Diabetes	0.54 (0.15, 1.90); 0.335	0.42 (0.09, 1.88); 0.260
Body mass index	1.05 (0.99, 1.12); 0.122	1.10 (1.01, 1.19); 0.022
STOP-BANG score	1.03 (0.74, 1.44); 0.848	0.99 (0.69, 1.43); 0.979

STOP-BANG, snoring, tired, observed apnea, high blood pressure, body mass index, age, neck circumference and gender.

Table V. BMI cut-off points of presence of respiratory disturbance index higher than apnea-hypopnea index in patients with obstructive sleep apnea.

BMI, kg/m^2	Sensitivity, %	Specificity, %
23.44-26.02	85.19	11.11
26.03-30.03	81.48	33.33
30.04-32.98	51.85	62.22
>32.99	40.74	80.00

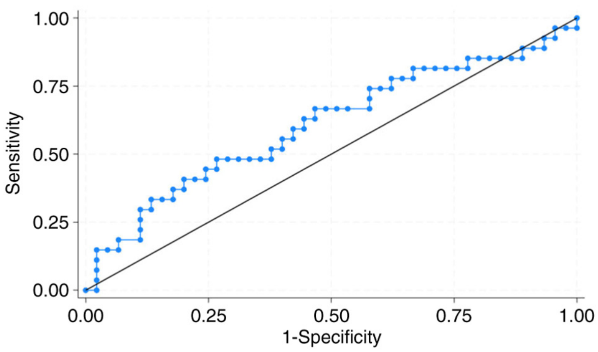

Figure 1. Receiver operating characteristic curve of body mass index on presence of respiratory disturbance index higher than apnea-hypopnea index [area under the curve, 60.66% (95% confidence interval 46.53%, 74.78%)].

according to univariate logistic regression and those associated with OSA were included in the multivariate logistic regression analysis (14,15). Hosmer-Lemeshow χ^2 was calculated for the predictive model to evaluate goodness of fit. All variables with >50% missing data were excluded from the predictive model (16). The significant numerical predictor was calculated for sensitivity and specificity using the area under the receiver operating characteristic (ROC) curve and an appropriate cutoff point for the numerical predictor was selected to provide a sensitivity ≥80%. Statistical analyses were performed in STATA version 18.5 (College Station). P<0.05 was considered to indicate a statistically significant difference.

Results

Of the 72 patients with OSA who met the inclusion criteria, 27 (37.50%) had an RDI higher than AHI. Clinical features of both groups are shown in Tables I and II. No significant difference in clinical features emerged between the groups in terms of age, sex, comorbidity or physical features. The RDI>AHI group had more patients with obesity (81.48 vs. 60.00%) and a higher body weight (85 vs. 70 kg) than the RDI=AHI group.

RDI>AHI group had a higher AHI (40.7 vs. 27.3 times/h) and RDI (53.6 vs. 27.3 times/h) than the RDI=AHI group (Table III). The lowest oxygen saturation was comparable between the groups (84 vs. 86%).

There were five factors in the predictive model for RDI higher than AHI: Age, sex, hypertension, diabetes, BMI and STOP-BANG score (Table IV). Only BMI was independently associated with RDI>AHI, with an adjusted odds ratio of 1.10 (95% confidence interval: 1.01, 1.19). The Hosmer-Lemeshow χ^2 value of the model was 4.03, which indicates goodness of fit.

The ROC curve of BMI for RDI>AHI was 60.66% (95% confidence interval: 46.53%, 74.78%; Fig. 1). BMI cutoff points for RDI>AHI are shown in Table V. A BMI of ≥26.03 kg/m^2 had a sensitivity of 81.48% and a specificity of 33.33%.

Discussion

Of all participants, 37.5% had an RDI higher than AHI; higher BMI is suggestive for RDI >AHI in patients with OSA. A previous study on the general population showed that the prevalence of patients with a RERA index ≥5 events/h is 3.8%, with a RERA index of 7.1 events/h, an RDI of 23.2 events/h and an AHI of 16.1 events/h (11). In the present study, 37.5% of patients with OSA had a higher RDI than AHI, with an RDI of 53.6 and AHI of 40.7 events/h. These differences may be explained by different study populations; the aforementioned study was a population-based study, whereas the present study was conducted with patients with OSA. As expected, the severity of OSA in patients with an RDI higher than AHI was more severe; the median RDI was 53.6 events/h, categorized as 'severe OSA', whereas the median RDI for individuals with an RDI equal to AHI was 27.3 events/h, classified as 'moderate OSA' (5). The RDI>AHI group may have demonstrated more severe OSA compared with the RDI=AHI group, with OSA severity potentially ranging from mild to severe and a median inter-group difference of 26.3 events/h. These findings are clinical significance, as the severity progression from mild to severe OSA has important treatment implications-specifically, severe OSA typically necessitates CPAP therapy (5).

The present study also showed that individuals with a high BMI, particularly >26.03 kg/m^2, may be at risk of having an RDI higher than AHI, with a sensitivity of 84.84%. Those patients may benefit from in-laboratory polysomnography more than HSATs because they may have more severe OSA defined by in-laboratory polysomnography. These results may differ from a previous study conducted with obese vs. non-obese patients with OSA in India (17). In the aforementioned study, there was a significantly lower proportion of patients with a RERA index >5 events/h in obese patients than in the non-obese group (29.16 vs. 52.12%). The aforementioned study classified obesity as a BMI of 27.5 kg/m^2, whereas the present study adopted a cutoff point of 26.03 kg/m^2 for having RDI higher than AHI. Moreover, the aforementioned study examined RERA index >5 events/h, whereas the present study focused on the median RDI index. Further studies are required to confirm the present results.

BMI and RERA are related. A previous study showed that patients with OSA with a low arousal threshold have significantly higher body fat than non-OSA patients based on visceral fat score (10.95 vs. 6.35) and body fat percentage (28.61 vs. 26.61) (18). The BMI among patients with a low arousal threshold and OSA was significantly higher than in the non-OSA group (25.99 vs. 22.74 kg/m^2). Those findings may indicate that having high BMI and OSA may be associated with a low arousal threshold that leads to higher RERA and RDI.

Although BMI may be a notable predictor of having an RDI higher than AHI, it has low specificity (33.33%). Therefore, clinical decision-making should integrate other factors such as oropharyngeal anatomy. BMI ≥26.03 kg/m^2 had a sensitivity of 81.48%; this cutoff point may be useful in screening. In patients with suspected OSA and with a BMI <26.03 kg/m^2, having RDI higher than AHI is unlikely, and using HSATs may be justified. By contrast, in-laboratory polysomnography may be suitable for patients with a BMI ≥26.03 kg/m^2.

The present study had limitations. First, the median BMI of the study population was ~30 kg/m^2. Thus, the present results may not be generalized to other populations such as non-obese or severely morbid obese patients. Differences in ethnic, anthropometric, healthcare systems and lack of external validation may also limit their applicability. Furthermore, variations in socioeconomic status, the presence of comorbidities, genetic polymorphisms and phenotypes may prevent generalized implementation. Second, RERA scoring may be scorer-dependent and lab-specific, with variability that may affect RERA burden and validity. An RDI higher than AHI also reflected RERA burden. Third, HSATs were not performed. Typically, AHIs based on HSATs are less than those based on in-laboratory polysomnography for 10 events/h (19), emphasizing the need for in-laboratory polysomnography. Fourth, no cardiovascular outcomes were measured. The area under the ROC curve for BMI was 60.66%, which indicated modest predictive ability. Finally, the study was conducted in a single center with a sample size that could have led to model instability. Additional large-sample studies with external validation are required to confirm the present results.

In conclusion, patients with suspected OSA with BMI ≥26.03 kg/m^2 may have higher RDI than AHI due to moderate to severe OSA. These patients may require in-laboratory polysomnography, whereas other patients may be tested by HSAT, which may report comparable AHI values.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

NL, SK and KS conceived and designed the study. SS and WB interpreted data. KS performed statistical analysis. All authors have read and approved the final manuscript. NL, SK and KS confirm the authenticity of all the raw data.

Ethics approval and consent to participate

The present study protocol was approved (approval no. HE641504) by the Ethics Committee in Human Research of Khon Kaen University (Khon Kaen, Thailand) and all methods were conducted following the principles of the Declaration of Helsinki. The requirement for informed consent was waived due to the retrospective nature of the study.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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