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BASET scoring: A novel simple biometric score for screening and grading obstructive sleep apnea

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A R T I C L E I N F O

Keywords:
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Validity

A B S T R A C T

Background: Polysomnography (PSG) is the gold-standard diagnostic tool for Obstructive Sleep Apnea (OSA). However, the availability of PSG is limited, and OSA is widely underdiagnosed; more than 80% of most developed nations undiagnosed. There is no diagnostic validated simple tool with clear cutoff point for predicting and roll out patient with OSA in primary care clinics significantly alters clinical outcomes.

Objectives: Our study aimed to assess the validity of BASET scoring as a new potential tool for screening and grading the severity of OSA patients.

Methods: After institution review board approval and formal patient consent, 144 subjects for suspected OSA and their relatives were enrolled. All subjects were subjected to a full night PSG study after history taking, sleep questionnaires, and physical examination, including BASET score components: **B**= Body Mass Index (BMI), **A**= Abdominal circumference (AC), S = Snoring, **E**= Epworth Sleepiness Scale, and T= Tongue teeth imprint. ROC analysis that used to assess the optimal cutoff point of the BASET score and to compare its accuracy for predicting OSA with Berlin and STOP-Bang scores.

Results: This study included 63 OSAS patients, 33 (52.38%) males and 30 (47.62%) females, and 81 controls; 22 (27.16%) males and 50 (72.84%) females. The Cronbach's alpha for the 5 BASET score components was 0.846, indicating the internal consistency reliability of the scale. Moreover, BASET score has a moderately strong positive significant correlation ($r = 0.778$, $p<0.001$) with AHI. By ROC analysis, the accuracy of the three measures was generally high, with BASET score predicting OSA most accurately (AUC=0.984, 95%CI: 0.956–0.999), followed by STOP-Bang (AUC=0.939, 95%CI: (0.887–0.972) and Berlin (AUC=0.901, 95%CI: 0.841–0.945). The AUC of BASET score was significantly higher compared to the Berlin score (difference= 0.0825, 95%CI: 0.039–0.125) and STOP-Bang score (difference= 0.0447, 95%CI: 0.011–0.078). On the other hand, there was no difference between the AUC of Berlin and STOP-Bang scores (difference=0.0378, 95%CI: 0.006 - 0.081 4). BASET score was significantly ($p<0.001$) associated with OSA grades,

Conclusion: BASET score is a convenient, reliable, and valid tool for diagnosing OSA. BASET score is more accurate for predicting OSA than Berlin and STOP-Bang scores, while there is no difference between Berlin and STOP-Bang scores. BASET score indicates OSA grades.

Registration of clinical trials by number: NCT05511974.

Name of the registry: ClinicalTrials.gov URL: https://clinicaltrials.gov/

1. Introduction

Obstructive sleep apnea (OSA) is a global health problem that is associated with increased cardiovascular morbidity and mortality, decreased quality of life, and a higher risk of traffic accidents due to hypersomnolence [1]. The prevalence of OSA, even though still underdiagnosed, has been investigated in different Western population cohorts, varying around 34% [2]. In Egypt, with a large population, the prevalence rate of diagnosed OSA is about 14% [3]. This incidence of OSA is expected to rise even more with the explosion of obesity

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epidemics worldwide [4].

Obesity is one of the most prominent risk factors for OSA; several studies demonstrate a strong association between being overweight and OSA [5,6]. Fat distribution in the body holds a substantial role in OSA development. For this reason, various anthropometric measurements, including body mass index (BMI) representing general obesity; abdominal circumference representing visceral obesity; and tongue imprint representing local obesity, are used throughout OSA patients' follow-up [7].

Snoring is also a significant social problem and contributes to decreased quality of life for bed partners through disrupted sleep. Snoring itself may have a negative health impact, such as an increased risk for cardiovascular disease [8]. Many patients with OSA experience excessive daytime sleepiness (EDS), which can negatively affect daily functioning, cognition, mood, and other aspects of well-being [9].

The reference standard for diagnosis of OSA is an overnight polysomnogram (PSG). However, the procedure is time-consuming, labor-intensive, and costly. Growing awareness of sleep apnea has extended many sleep laboratories' long waiting lists [10].

Moreover, PSG requires the expertise of sleep medicine specialists, who may not be readily available at many hospitals and medical centers. All these factors exacerbate delays that can prevent prompt diagnosis and treatment of OSA, further emphasizing the vital need for a simple, practical, and reliable method of identifying and triaging patients at high risk of OSA. In an effort to deal with this issue, a number of screening tests have been developed to identify high-risk patients [11–14].

In this study, we aimed to develop and assess the validity of the BASET score as a new potential tool for screening and grading the severity of OSAS patients and as a screening tool for the risk factors of OSAS. We also shed light on the difference in performance between BASET and the previously most commonly used questionnaires, Berlin and STOP-Bang.

2. Methods

Ethical statement

The study protocol was approved by the institutional review board of the Faculty of Medicine, Mansoura University (approval code number: R.22.06.747). The Helsinki declaration and the guidelines set by the institutional ethics committee were adhered to in all aspects of this study's activities. Participants in the study provided written informed consent. We follow the STARD checklist.

2.1. Study participants

The study included 144 consecutive adult subjects attending the outpatient clinic of sleep disorders breathing unit, chest department, Mansoura University Hospital during the period from July to September 2022. They were either OSA-suspected patients or their relatives. The exclusion criteria were patients with neuromuscular diseases, craniofacial disorders, hypothyroidism, congestive cardiac failure, chronic renal failure, and chronic pulmonary diseases.

2.2. Sample size calculation

It is recommended to include 5 to 20 participants per item on the scale when testing the validity and reliability of a new tool [15]. Because the BASET score comprised five items, the sample size was calculated to be between 25 and 100 subjects. We enrolled 144 individuals to strengthen the study power and reliability of the results.

2.3. Study procedures

All recruited participants underwent a clinical interview, anthropometric measurements, tongue examination, the developed BASET scoring, and whole-night polysomnography (PSG). The clinical interview included: a) collecting personal data like age and sex; b) a smoking history (smoker and non-smoker); c) a history of chronic diseases such as arterial hypertension and diabetes mellitus; d) evaluating snoring loudness and frequency; e) assessing excessive daily sleepiness using the Epworth Sleepiness Scale (ESS) (a total score of $\geq$ 10 was considered as pathological sleepiness) [16]; f) screening for OSA using the Arabic Berlin questionnaire and STOB-Bang questionnaire (a score of $\geq$ 2 and $\geq$ 3, respectively were considered positive OSA [17,18].

The anthropometric measurements comprised: a) calculation of the body mass index (BMI) in kg/m^2; b) measurement of the abdominal circumference using a flexible tape with a metric scale according to guidelines by the World Health Organization (WHO) at the midpoint between the last rib and the iliac crest, and at the level of the largest lateral extension of the hips, respectively, both in a horizontal plane. Abnormal AC was considered when the AC value was $\geq$ 88 cm for females and $\geq$ 102 cm for males [19]. The lateral borders of the tongue were examined to evaluate the type of tongue-teeth imprint [20].

The authors developed the BASET score after an extensive review of the literature. The questionnaire included anthropometric measurements such as **B**ody mass index (kg/m^2) and **A**bdominal circumference (cm), **S**noring frequency and loudness, **E**xcessive daily sleepiness using ESS [[21]], and **T**ongue-teeth imprint. [[20]] The BASET score ranged from 0 to 10. BMI ranked on 3 points scale (0= <30 kg/m^2, 1= 30–35 kg/m^2 and 2= $\geq$ 35 kg/m^2). Abdominal circumference gave a score of 0 when normal and 1 when abnormal. Snoring ranked on 3 points scale (0 = no snoring and snoring not louder than talking, 1= snoring less than 3–4 times/week and snoring louder than talking, 2= snoring frequency $\geq$3–4 days/week and snoring louder than talking. Also, ESS ranked on 3 points scale (0 = Epworth score < 10, 1 = Epworth score 10–15, 2 = 16–24). Teeth-tongue imprints were ranked on 4 points scale (0 = region which is neither concave nor dark red, 1= region which is dark red but not concave, 2 = region which is concave but not dark red, 3 = region which is dark red and concave).

All subjects (as shown in the below flow chart) experienced standard full-night polysomnography using (somnoscreen plus with serial number **3038** and second one with serial number **6357)** according to the American Academy of Sleep Medicine guidelines for assessment for OSA [22]. The apnea hypopnea index (AHI) for the participants was used to identify and assess the degree of OSA. Participants were assigned to a non-OSA group (AHI <5) and an OSA group (AHI $\geq$ 5). OSA patients were furtherly graded into mild OSA (AHI <15), mild to moderate OSA (AHI 15–30), and severe OSA (AHI $\geq$30).

2.4. Statistical analysis

Statistical analysis procedures were done using the IBM SPSS Statistics version 22 software package (IBM Corp., Armonk, NY, USA). Kolmogorov–Smirnov's test was used to assess continuous variables' normality distribution. All continuous data were summarized as mean and standard deviation values and compared between two groups using the Student's t-test or Mann-Whitney *U* test, depending on the data distribution. ANOVA test was used to compare BASET scores between different OSA grades with a post hoc test for pair-wise comparisons. Categorical variables were associated via the Chi-square test. Pearson's correlation coefficient was used to evaluate the correlation between the BASET score and AHI (events/hr.). Univariate and multivariable logistic regression analyses were utilized to explore the association between OSA risk and BASET components. The outcome variable was OSA (OSA group vs. non-OSA group), and the following BASET score components were the predictors: BMI, AC, Snoring, EDS, and Tongue-teeth imprints. Odds ratios (OR) and 95% confidence intervals (95% CIs) were measured to identify the significant factors. A receiver operating characteristic (ROC) curve was created using MedCalc Statistical Software version 19.2.6 (MedCalc Software bv, Ostend, Belgium) to calculate the optimal cutoff value of the BASET score in detecting patients with OSA. Optimal cutoff point was defined as the point in the ROC curve with the highest possible sensitivity and the highest possible specificity to classify most of the examined participants correctly [23]. The accuracy of the BASET, Berlin and STOP-Bang questionnaires was compared using the area under the curve (AUC). P-values of $\leq$ 0.05 were considered statistically significant. Internal consistency reliability of BASET components was evaluated by measuring the coefficient of Cronbach's alpha.

We have 2 full PSG Somonoscreen plus really working 52 case/month from June to September subjects actually took appointment for full PSG & their relatives accepted doing the study at the same night.

3. Results

The personal and clinical characteristics of the 144 study participants are presented in Table 1. The study included 63 OSA patients, 33 (52.38%) males and 30 (47.62%) females, and 81 controls; 22 (27.16%) males and 59 (72.84%) females. Frequencies of males, smokers, positive teeth imprints, hypertension, and diabetes were significantly higher in OSA patients than in controls. Similarly, age, BMI, AC for males and females, Epworth sleepiness score, Berlin questionnaire score, STOP-Bang score, and AHI were significantly higher compared to controls. On the other hand, patients with OSA had significantly lower sleep efficiency and average SPO^2%.

Table 2. Shows the results of unilabiate logistic regression of BASET components for predicting OSA. The analysis indicated that BMI 30–35 (OR= 3.993), abnormal AC [OR =31.202), snoring1 [OR=26.667, 95% CI: 3.345–212.570], snoring2 (OR=230.00), Epworth score10 - 15 (OR=2.995), teeth imprint: region which is dark but not concave (OR=64.750), and region which is concave but not dark red (OR=271.333), were associated with high odds of OSA. The multivariable logistic regression analysis revealed that the independent predictors for OSA were snoring (OR=11.588), followed by teeth imprint (OR=8.989).

The Cronbach's alpha for the 5 BASET score components was 0.846, indicating the internal consistency reliability of the scale.

Fig. 1 indicates a moderately strong positive significant correlation (r = 0.778, p<0.001) between total BASET score AHI. It also describes the linear regression equation for predicting AHI.

In Fig. 2 and Table 3, ROC analysis was used to assess the optimal cutoff point of the BASET score and to compare its accuracy for predicting OSA with Berlin and STOP-Bang scores. The optimal cutoff value of the BASET score was 5 (sensitivity =88.89%), and specificity = 97.53). The accuracy of the three measures was generally high, with BASET score predicting OSA most accurately (AUC=0.984) followed by STOP-Bang (AUC=0.939), and Berlin (AUC=0.901), The AUC of the BASET score was significantly higher compared to the Berlin score (difference= 0.0825), and the STOP-Bang score (difference= 0.0447). On the other hand, there was no difference between the AUC of Berlin and the STOP-Bang scores (Table 4).

Fig. 3 reveals that the mean values of BASET score were significantly (p<0.001) associated with OSA grades, with a mean value of 1.81 (95% CI: 1.42–2.21) for non-OSA, a mean value of 6.94 (95%CI: 6.15–7.73) for mild to moderate OSA and a mean value of 8.16 (95%CI: 7.65–8.66).

Table 1
Personal and clinical characteristics of the study groups.

Variables	Non-OSA N=81	OSA N=63	P-value
Age	38.53 ± 10.35	51.94 ± 10.36	< 0.001
Sex (male/female)	22/59	33/30	0.003
Smoking	7 (8.6)	23 (36.5)	< 0.001
BMI (kg /m^2)	28.37 ± 6.93	41.94 ± 9.10	< 0.001
Abdominal Circumference (cm)			
Male	82.41 ± 11.504	124.82 ± 17.08	< 0.001
Female	93.05 ± 21.144	131.83 ± 14.58	< 0.001
Teeth imprint:			
Region is neither concave nor dark red	74 (91.4)	2(3.2)	< 0.001
Region which is dark but not concave	4 (4.9)	7(11.1)	
Region which is concave but not dark red	3 (3.7)	22(34.9)	
Region which is dark red and concave	0 (0)	32(50.8)	
Epworth scale score	9.04 ± 2.09	13.90 ± 5.87	< 0.001
Berlin questionnaire	1.47 ± 0.87	2.79 ± 0.48	< 0.001
STOP-Bang score	2.31 ± 1.44	5.67 ± 1.50	< 0.001
Sleep efficiency	87.75 ± 6.22	78.57 ± 16.08	< 0.001
Apnea hypopnea index (hrs.)	3.50 ± 1.49	49.74 ± 28.78	< 0.001
Average SPO^2 (%)	94.89 ± 1.32	92.11 ± 4.69	< 0.001
Minimal SPO^2 (%)	81.15 ± 24.21	76.73 ± 10.59	0.144
Hypertension	15 (18.5)	35 (55.6)	0.001
Diabetes Mellitus	1 (1.2)	20 (31.7)	0.001

4. Discussion

OSA is a global health underdiagnosed problem affecting nearly one billion people worldwide in age period between 30 and 69 years [24]. The present study validates the BASET score as a new potential tool for screening and grading OSA patients. This tool is proposed to assist non-specialists in detecting and grading OSA and help uncover the hidden portion of the widespread disease.

The prevalence of OSA has appeared to be increasing over the last decade, and its rate of increase is associated with the rising rate of obesity [25], which is consistent with our findings, as we observed an increased risk of OSA among subjects with a higher BMI. Furthermore, the majority of existing evidence indicates a stronger relationship between waist circumference and OSA than with general obesity. Also, upper airway narrowing is a more significant risk factor for OSA than general and visceral obesity. In the present study, tongue obesity indicates local upper airway obesity, which was evaluated by teeth tongue imprints. In BASET score we use three objective measurements (BMI, abdominal circumference, teeth imprint), in addition to two subjective measurements excessive day time sleepiness and snoring which are already graded.

Diagnostic testing for OSA should be performed on patients with excessive daytime sleepiness (EDS) on most days and at least two of the following clinical features of OSA: a history of habitual loud snoring, witnessed apnea or gasping or choking while sleeping, and a diagnosis of systemic hypertension [26]. This recommendation strongly supports the inclusion of both snoring and excessive daytime sleepiness in our scoring, giving the score a higher performance than the Berlin and Stop-Bang questionnaires. For this reason, we employed these five BASET components in our innovative, reliable, and validated scale.

The STOP-Bang questionnaire (SBQ), the Berlin questionnaire (BQ), and the Epworth Sleepiness Scale (ESS) are the most commonly used OSA evaluation tools. Importantly, none of these screening tools should be used in place of sleep apnea testing. We agree with the American Academy of Sleep Medicine (AASM) that the STOP-Bang questionnaire is being increasingly used as a preoperative evaluation tool to detect undiagnosed OSA patients who may be at risk of perioperative complications [27]. With reviewing of most published data about OSA screening to improve early screening and grading we found that, STOP-Bang questionnaire is the most sensitive of the commonly used

Table 2
Logistic regression analysis of BASET components for predicting OSA.

BASET components		Point of score	Univariate analysis		Multivariable analysis[a]	
			OR (95% CI)	P-value	OR (95% CI)	P-value
BMI (Kg/m^2):	**< 30**	0	Ref.	–	1.007 (0.835–1.214)	0.942
	30–35	1	3.993 (1.282–12.434)	0.017		
	≥ 35	2	38.700 (12.229–122.469	< 0.001		
AC:	**Normal**	0	Ref.	< 0.001	1.055(0.964–1.155)	0.243
	Abnormal	1	31.202 (10.232–95.1460			
Snoring:						
No snoring or snoring not louder than talking		0	Ref.	–	11.588 (1.013–132.58)	0.049
Snoring < 3–4/wk and snoring louder than talking		1	26.667 (3.345–212.570)	0.002		
Snoring ≥3–4/wk. and snoring louder than talking		2	230.00 (27.984–1890.38)	< 0.001		
Epworth score	**< 10**	0	Ref.	–	1.019 (0.772–1.343)	0.896
	10–15	1	2.995 (1.316–6.81)	< 0.001		
	16–24	2	–	–		
Tongue-Teeth imprint:						
Region is neither concave nor dark red		0	Ref	–	8.989 (2.994–26.990)	<0.001
Region which is dark but not concave		1	64.750 (10.020–418.421)	< 0.001		
Region which is concave but not dark red		2	271.333 (42.603–1728.07)	< 0.001		
Region which is dark red and concave		3	–	–		

Ref.= reference group, [a]BASET components entered multivariable regression as continuous variables, OR (95% CI) = odds ratio (95% confidence interval), BMI= Body mass index, AC= abdominal circumference (Abnormal ≥ 88 for females and ≥ 102 for males).

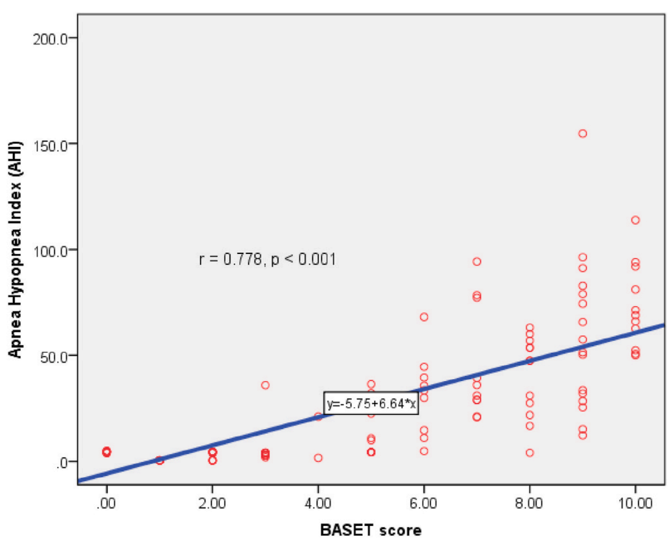

Fig. 1. Correlation between BASET score and apnea hypopnea index (AHI).

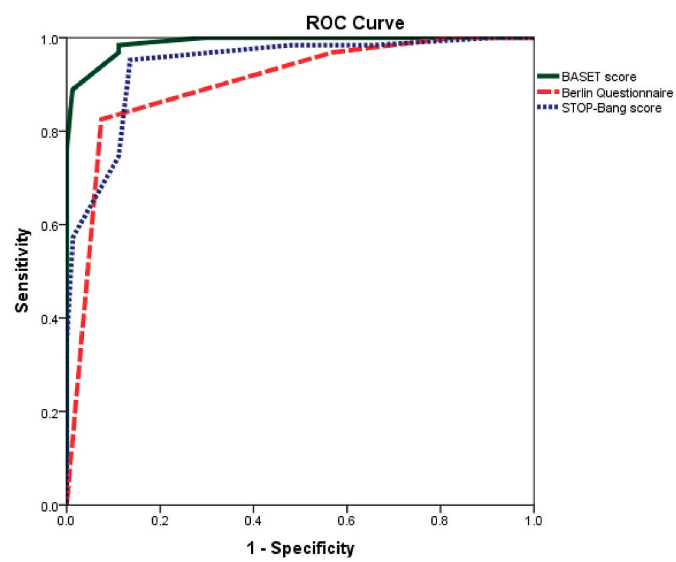

Fig. 2. Receiver Operating Characteristic (ROC) analysis of Berlin, STOP-Bang and BASET scores for predicting obstructive sleep apnea (OSA).

screening questionnaire for OSA (Epworth sleepiness scale, Berlin Questionnaire), but has low specificity. In 2020 Oktay Arslan and his college through large number study for evaluation of the 3 commonly used questionnaire concluded that The STOP-Bang questionnaire, with its high sensitivity, may be useful for screening OSA. However, the low specificity should be improved in the questionnaire [28]. In 2022, US Preventive Services Task Force (USPSTF) strong recommend need for more specific and simple used questionnaire reliable for in general population screening of OSA [29].

In general, these screening tools display poor accuracy in the sleep clinic for any level of selected apnea-hypopnea index (AHI) stratification and are rarely, if ever, used in clinical practice by sleep experts. However, while non-sleep experts may use these tools in practice, their validity in that setting remains questionable [27].

Because it is critical to screen patients at high risk for OSA, a recent study compared the predictive probabilities of the three most commonly used questionnaires in screening OSAS: the ESS, SBQ, and BQ. They concluded that SBQ and BQ appear to be the best screening tools, with SBQ outperforming BQ in detecting severe OSA [28]. In the current study, the BASET score outperformed both the BQ and the SBQ in terms of accuracy. The BASET scoring of five components showed internal consistency reliability. With an optimal cutoff value of five, ROC analysis revealed that the BASET score predicted OSA more accurately than SBQ and BQ. Moreover, the AUC of the BASET score was significantly higher compared to the BQ and SBQ. On the other hand, there was no difference between the AUC of Berlin and STOP-Bang scores.

Table 3
Results of receiver operating characteristics of evaluating parameters for predicting obstructive sleep apnea.

Evaluating parameter	AUC (95%CI)	Optimal cutoff	Sensitivity (95% CI)	Specificity (95% CI)	P-value
Berlin	0.901 (0.841–0.945)	≥2	82.54 (70.9–90.9)	92.59 (84.6–97.2)	0.001
STOP-Bang	0.939 (0.887–0.972)	≥ 3	95.24 (86.7–99.0)	86.42 (77.0–93.0)	0.001
BASET	0.984 (0.956–0.999)	≥5[a]	88.89 (78.4–95.4)	97.53 (91.4–99.7)	0.001

[a] BASET score [0-10] if ≥5 means positive = risk for OSA.

Furthermore, BASET score was significantly related to OSA grades,

Table 4
Pairwise comparison of ROC curves for predicting OSA.

	Difference between AUC	95% CI	p-value
BASET vs. Berlin	0.0825	0.039–0.125	< 0.001
BASET vs. STOP-Bang	0.0447	0.011–0.078	0.009
Berlin vs. STOP-Bang	0.0378	−0.006 - 0.081	0.089

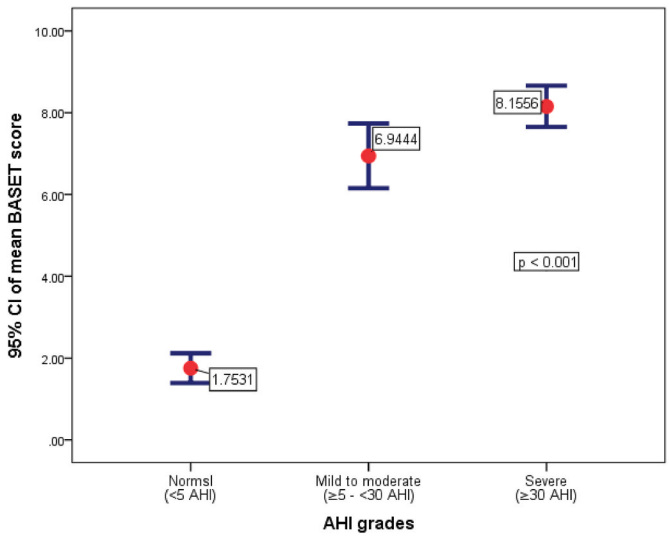

Fig. 3. Mean and 95% confidence interval (CI) of BASET score for AIH grades.

with non-OSA average scores of 1.81, mild to moderate OSA score of 6.94, and severe OSA score of 8.16. Based on the study's findings, we anticipate that the BASET score will be a valuable tool in facilitating the screening and raising awareness of OSA, the most common sleep-related breathing disorder.

This study had some strengths, including high internal consistency reliability, as measured by Cronbach's alpha, and higher diagnostic accuracy of the BASET score when compared to previous screening tools. Also, the majority of the score's components are objective. Moreover, the five components are simple and easy to perform, not only at the sleep clinic or with general practitioners but they can also be self-evaluated. Thus, the BASET score could be used as a self-assisted tool for large-scale OSA screening. Researchers assume that this tool might aid in uncovering the hidden portion of the OSA iceberg.

Limitations of the study are mostly related to utilizing a single-center setting. Also, the study was conducted in a sleep clinic population, which may affect the generalizability of the results. A large-scale multicenter study with a large number of subjects with different grades of OSA is recommended to provide more insight into the performance of the BASET tool for diagnosing and grading OSA in a large population.

5. Conclusion

BASET score is a convenient, reliable, and valid tool for screening OSA. BASET score is more accurate for predicting OSAS than BQ and SBQ. Additionally, BASET score was significantly associated with OSAS grades.

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None to declare.

CRediT authorship contribution statement

Magda A. Ahmed: Investigation, Writing – review & editing, Supervision. **Nabil J. Awadalla:** Methodology. **Amira A.M.M. Attia:** Writing – review & editing.

Declaration of competing interest

Conflict of interest: The authors declare no conflict of interest.

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None to declare.

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