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# Validation of the STOP, STOP-BANG Questionnaire and Its Modifications for Screening Obstructive Sleep Apnea in Southern Thailand

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## Abstract:

**Objective:** To evaluate the diagnostic performance of STOP, STOP-BANG, and their modifications against apnea-hypopnea index (AHI) cutoffs of ≥5 and ≥15.

**Material and Methods:** This retrospective cross-sectional study analyzed OSA patients (≥18 years) treated at the Dental Sleep Medicine Clinic, Prince of Songkla University, Thailand, from December 2007 to April 2021. Screening tools included STOP, STOP-BANG, and modified versions with different body mass index (BMI) and NC cutoffs. Patients were classified by AHI (≥5 and ≥15), and the accuracy of each questionnaire was evaluated against these thresholds.

**Results:** Of the 112 eligible patients, 66.1% were male, with a mean age of 46.9±11.9 years. For AHI ≥5, sensitivities were high: STOP (93.1%), STOP-BANG (89.8%), and modified STOP-BANG with BMI ≥30/NC ≥40 (90.8%), BMI ≥26/NC ≥40 (93.9%), and BMI ≥35/NC ≥35 (93.8%). Specificities were moderate: STOP (45.5%), STOP-BANG (54.5%), and 45.5% for all modified versions. For AHI ≥15, sensitivities remained high: STOP (91.3%), STOP-BANG (89.4%), BMI ≥30/NC ≥40 (87.9%), BMI ≥26/NC ≥40 (93.9%), and BMI ≥35/NC ≥35 (92.3%). However, specificities were low: STOP (14.0%), STOP-BANG (16.3%), modified STOP-BANG with BMI ≥ 30/NC ≥ 40 (18.6%), BMI ≥26/NC ≥40 (16.3%), and BMI ≥35/NC ≥35 (14.3%).

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**Conclusion:** The modified STOP-BANG (BMI ≥26 kg/m$^2$, NC ≥40 cm) showed the highest sensitivity and may be the most suitable OSA screening tool in our region.

**Keywords:** body mass index, diagnostic accuracy, neck circumference, obstructive sleep apnea, STOP, STOP-BANG

## Introduction

Obstructive sleep apnea (OSA) is a prevalent sleep-related breathing disorder characterized by recurrent episodes of partial or complete upper airway collapse during sleep, leading to hypopneas (reduced airflow) or apneas (complete cessation of airflow). These episodes can lead to intermittent hypoxia, sleep fragmentation, and substantial physiological stress, all of which are associated with a variety of adverse health outcomes, including cardiovascular disease, stroke, type 2 diabetes, and cognitive impairment[1,2]. The prevalence of obstructive sleep apnea (OSA) in Thailand varies by methods of survey, population, and study setting. For instance, a clinical-based study at Songklanagarind Hospital involving 929 individuals found that 85.6% were diagnosed with OSA, and 52.7% met the criteria for obstructive sleep apnea syndrome (OSAS), defined as an apnea–hypopnea index (AHI) >5 events/h with the presence of excessive daytime sleepiness (EDS)[3]. Whereas, another study found a lower overall OSA prevalence of 11.4%, with 4.4% meeting the criteria for OSAS[4].

Awareness of OSA has increased in Thailand, but access to polysomnography (PSG), the diagnostic gold standard, remains limited, particularly in resource-limited settings. This highlights the need for simple, effective screening tools to identify individuals at risk. The STOP and STOP-BANG questionnaires, widely used for preoperative OSA screening, offer high sensitivity but limited specificity, especially in Asian populations[5]. Due to anatomical and anthropometric differences, validating these tools in the Thai population is essential to ensure their accuracy and clinical relevance.

The STOP questionnaire demonstrated sensitivities of 65.6%, 74.3%, and 79.5%, and specificities of 60.0%, 53.3%, and 48.6% at AHI thresholds greater than 5, 15, and 30 events per hour, respectively[6]. While these values reflect strong potential for identifying high-risk individuals, the relatively low specificity suggests that many individuals without OSA may still be flagged as at risk, possibly leading to unnecessary testing. To address these limitations, several modifications have been proposed and evaluated within the Thai population. Research conducted in Thailand has provided valuable insights into the performance of these questionnaires within the local population. One such modification includes the incorporation of the waist-to-height ratio (WHtR); it was reported that a WHtR cutoff of ≥0.55 significantly improved specificity to 85.2% for AHI ≥5, without sacrificing sensitivity[6]. This adjustment underscores the potential of population-specific modifications to enhance the diagnostic accuracy of screening tools, especially among individuals whose body habitus differs from the Western populations for which the original questionnaire was developed.

Another area of clinical interest is the predictive value of the STOP-BANG questionnaire in perioperative settings. Sangkum et al. reported that the modified STOP-BANG score could effectively predict perioperative adverse events, with a notable incidence of 23.2% in patients categorized as high risk[7]. These findings emphasize the relevance of OSA screening beyond sleep medicine and into surgical and anesthetic risk assessment. Similarly, adjustments to body mass index (BMI) and neck circumference (NC) thresholds,- specifically 25 kg/m$^2$ for BMI and 36 cm for NC, - have been proposed as more suitable cutoffs for the Thai population[8], with corresponding sensitivities and specificities of 97.2% and 91.4% for BMI, and 94.7% and 82.9% for NC. This further supports the need for ethnically appropriate screening parameters.

Therefore, while the STOP and STOP-BANG questionnaires remain valuable tools for screening OSA across the Thai population, ongoing efforts to optimize their specificity are essential. Modifications such as incorporating WHtR and adjusting BMI and NC cutoffs have shown promise in improving diagnostic accuracy. Although national data provide a broad perspective, this study specifically aims to assess how well the STOP and STOP-BANG questionnaires and its modifications perform in the southern region of Thailand, recognizing that regional population characteristics may further influence screening effectiveness.

## Material and Methods

### Study design

This retrospective cross-sectional study analyzed data from December 2007 to April 2021 on patients treated at the Dental Sleep Medicine Clinic, Dental Hospital, Faculty of Dentistry, Prince of Songkla University, Thailand. Ethical approval was granted by the Human Research Ethics Committee of the Faculty of Dentistry, Prince of Songkla University (EC6409-062, 2021).

### Participants and data collection

The study included male and female patients aged 18 and older who had completed clinical examinations and had available medical data on STOP, STOP-BANG scores, and AHI from polysomnography. Patient characteristics included gender, age, body mass index (BMI), neck circumference (NC), and marital status. To enhance reliability and minimize inter-rater variability, all diagnoses were conducted by a single expert.

The screening tools for OSA included the STOP and STOP-BANG questionnaires. The STOP questionnaire consists of four yes-or-no questions addressing common symptoms: loud snoring, frequent daytime tiredness, observed apneas during sleep, and the presence or treatment of high blood pressure[9]. A score of two or more positive answers indicates a high risk for OSA. The STOP-BANG questionnaire expands on the STOP tool by adding four additional items[10]. These include BMI greater than 35 kg/m$^2$, age over 50 years, NC greater than 40 cm, and male gender. A STOP-BANG score of ≥3 out of 8 indicated a risk of OSA. Various cutoff criteria for BMI and NC were applied in this study, including modified STOP-BANG BMI ≥30, NC ≥40; modified STOP-BANG BMI ≥26, NC ≥40; and modified STOP-BANG BMI ≥35, NC ≥35. AHI values from polysomnography were used to categorize patients into groups with AHI ≥5 and AHI ≥15.

### Statistical analysis

Patient characteristics were reported as frequency and percentage. The accuracy of each questionnaire in detecting OSA at different AHI thresholds was assessed using diagnostic performance measures, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive and negative likelihood ratios (LR+ and LR-), and the area under the receiver operating characteristic (ROC) curve, with 95% confidence intervals (CI).

## Results

A total of 168 patients were assessed, of whom 112 met the inclusion criteria. Fifty-six patients were excluded due to being under 18 years old, lacking PSG results, missing STOP questionnaire data, or missing BMI and NC measurements. Among 112 patients, there was male predominance (66.1% male, 33.9% female) (Table 1). The mean age was 46.85 years (S.D. 11.89), with females averaging 50 years (S.D. 9) and males 45 years (S.D. 13). Regarding marital status, most patients were married or had a partner (73.2%), while 23.2% were single, and 3.6% were widowed or divorced. The mean BMI was 25.62

**Table 1** Demographic data of the study population

| **Characteristics (n=112)** | **Category** | **Value** |
|---|---|---|
| Sex, n (%) | Female | 38 (33.9) |
| | Male | 74 (66.1) |
| Age in years (mean, S.D.) | Total | 46.85, 11.89 |
| | Female | 50, 9 |
| | Male | 45, 13 |
| Marital status, n (%) | Single | 26 (23.2) |
| | Married/Partner | 82 (73.2) |
| | Widow/Divorced | 4 (3.6) |
| BMI (mean, S.D.) | Total | 25.62, 4.50 |
| | Female | 25.50, 4.62 |
| | Male | 25.68, 4.46 |
| AHI event/hour, n (%) | Total | 112 (100) |
| | AHI <5 | 10 (8.9) |
| | AHI ≥5, <15 | 34 (30.4) |
| | AHI ≥15, <30 | 43 (38.4) |
| | AHI ≥30 | 25 (22.3) |
| **Presence of comorbidities** | | **n (%)** |
| Hypertension | | 27 (24.1) |
| Cardiovascular diseases | | 7 (6.3) |
| Diabetes Mellitus | | 4 (3.6) |
| Dyslipidemia | | 7 (6.3) |
| Anxiety | | 5 (4.5) |
| Depression | | 6 (5.4) |

AHI=apnea-hypopnea index, BMI=body mass index, S.D.=Standard deviation

(S.D. 4.50), with similar values for both genders (25.50 for females and 25.68 for males). Among comorbidities, the most common was hypertension (24.1%). Most of the participants had moderate OSA (38%), defined as an AHI of ≥15 to <30 events per hour.

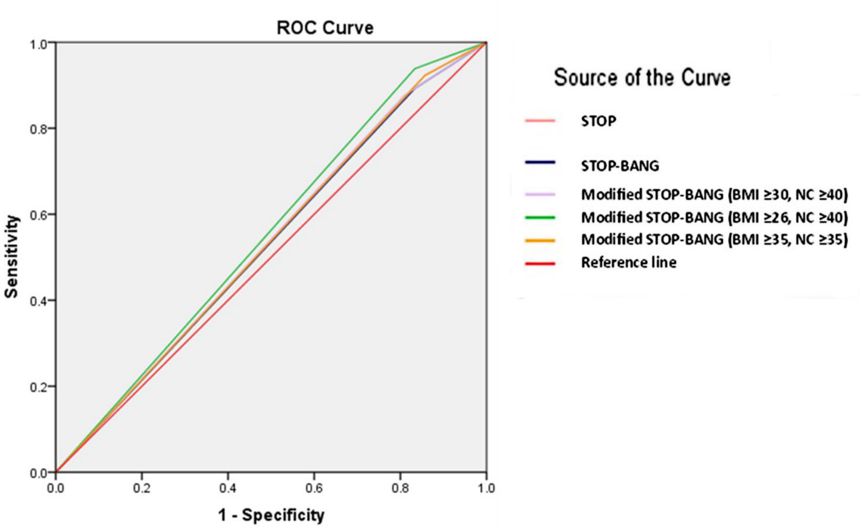
According to Table 2, at AHI ≥5, the highest sensitivity was observed in the modified STOP-BANG with BMI ≥26 and NC ≥40, 93.9% (95% CI, 87.2–97.7), followed by the modified STOP-BANG with BMI ≥35 and NC ≥35, 93.8% (86.9–97.7), STOP, 93.1% (86.2–97.2), modified STOP-BANG with BMI ≥ 30 and NC ≥40, 90.8% (83.3–95.7), and STOP-BANG, 89.8% (82.0–95.0). Among the screening tools, STOP-BANG demonstrated the highest specificity at 54.5% (23.4–83.3), while the other tests each showed 45.5% (16.8–76.6). The highest PPV was found in STOP-BANG, 94.6% (86.7–98.5), followed by STOP, 94.0% (85.8–98.0). The NPV was highest in the modified STOP-BANG with BMI ≥ 35 and NC ≥35 and in BMI ≥26 and NC ≥40, both at 45.5% (16.8–76.6). The LR+ was highest in STOP-BANG, 2.0 (0.8–4.9), while the lowest LR– was shared by STOP, STOP-BANG, and the modified STOP-BANG with BMI ≥30 and NC ≥40, all at 0.2 (0.1–0.5). Lastly, the largest area under the ROC curve (AUC) was observed in the modified STOP-BANG with BMI ≥30 and NC ≥40, 0.721 (0.582–0.860) (Figure 1).

In Table 3, at AHI ≥15, the highest sensitivity was observed in the modified STOP-BANG with BMI ≥ 26 and NC ≥40, 93.9% (95% CI, 85.2–98.3), followed by the modified STOP-BANG with BMI ≥35 and NC ≥35, 92.3% (82.9–97.5), STOP, 91.3% (82.0–96.7), modified STOP-

**Table 2** Accuracy of STOP and STOP-BANG Screening Tools at Different BMI and Neck Circumference Thresholds for AHI ≥5

| Screening test | Sensitivity (95%CI) | Specificity (95%CI) | PPV (95%CI) | NPV (95%CI) | LR+ (95%CI) | LR− (95%CI) | AUC (95%CI) |
|---|---|---|---|---|---|---|---|
| STOP | 93.1<br>(86.24-97.17) | 45.5<br>(16.75-76.62) | 94.0<br>(90.11-96.42) | 41.7<br>(21.40-65.20) | 1.7<br>(0.99-2.93) | 0.2<br>(0.06 -0.40) | 0.696<br>(0.50–0.890) |
| STOP-BANG BMI ≥35, NC ≥40 | 89.8<br>(82.03-95.00) | **54.5**<br>**(23.38-83.25)** | **94.6**<br>**(90.18-97.12)** | 37.5<br>(21.28-57.12) | **2.0**<br>**(1.03-3.79)** | 0.2<br>(0.08-0.42) | 0.680<br>(0.488–0.872) |
| Modified STOP-BANG BMI ≥30, NC ≥40 | 90.8<br>(83.28-95.71) | 45.5<br>(16.75-76.62) | 93.7<br>(89.60-96.23) | 35.7<br>(18.45-57.70) | 1.7<br>(0.97-2.87) | 0.2<br>(0.08-0.50) | **0.721**<br>**(0.535-0.906)** |
| Modified STOP-BANG BMI ≥26, NC ≥40 | **93.9**<br>**(87.15-97.72)** | 45.5<br>(16.75-76.62) | 93.9<br>(89.92-96.35) | **45.5**<br>**(23.28-69.59)** | 1.7<br>(1.00-2.96) | **0.1**<br>**(0.05-0.37)** | 0.696<br>(0.502–0.890) |
| Modified STOP-BANG BMI ≥35, NC ≥35 | 93.8<br>(86.89-97.67) | 45.5<br>(16.75-76.62) | 93.8<br>(89.72-96.27) | **45.5**<br>**(23.29-69.58)** | 1.7<br>(1.00-2.96) | **0.1**<br>**(0.05-0.38)** | 0.696<br>(0.502–0.890) |

AHI=apnea-hypopnea index, BMI=body mass index, NC=neck circumference, PPV=positive predictive value, NPV=negative predictive value, LR+=positive likelihood ratio, LR-=negative likelihood ratio, AUC=area under the receiver operating characteristic (ROC) curve



AHI=Apnea-Hypopnea Index, BMI=Body Mass Index, NC=Neck Circumference

**Figure 1** The Receiver Operating Characteristic (ROC) curve of the STOP and STOP-BANG screening tools at various BMI and neck circumference thresholds for AHI ≥5. Among the models, the modified STOP-BANG BMI ≥30, NC ≥40 (pink line) exhibited the largest area under the ROC curve.

**Table 3** Accuracy of STOP and STOP-BANG screening tools at different BMI and neck circumference thresholds for AHI ≥15

| Screening test | Sensitivity | Specificity | PPV | NPV | LR+ | LR- | AUC (95%CI) |
|---|---|---|---|---|---|---|---|
| STOP | 91.3 (82.03-96.74) | 14.0 (5.30-27.93) | 63.0 (59.67-66.22) | 50.0 (25.62-74.38) | **1.1 (0.92-1.22)** | 0.6 (0.21-1.81) | 0.533 (0.419-0.646) |
| STOP-BANG BMI ≥35, NC ≥40 | 89.4 (79.36-95.63) | 16.3 (6.81-30.70) | 62.1 (58.38-65.70) | 50.0 (27.39-72.61) | **1.1 (0.91-1.25)** | 0.7 (0.25-1.73) | 0.529 (0.416-0.643) |
| Modified STOP-BANG BMI ≥30, NC ≥40 | 87.9 (77.51-94.62) | **18.6 (8.39-33.40)** | 62.4 (58.33-66.23) | 50.0 (28.87-71.13) | **1.1 (0.91-1.28)** | 0.7 (0.26-1.61) | **0.534 (0.420-0.647)** |
| Modified STOP-BANG BMI ≥26, NC ≥40) | **93.9 (85.20-98.32)** | 16.3 (6.81-30.70) | **63.3 (59.83-66.57)** | **63.6 (35.27-84.90)** | **1.1 (0.97-1.30)** | **0.4 (0.12-1.20)** | 0.553 (0.439-0.666) |
| Modified STOP-BANG BMI ≥35, NC ≥35 | 92.3 (82.95-97.46) | 14.3 (5.43-28.54) | 62.5 (59.12-65.77) | 54.5 (28.10-78.65) | **1.1 (0.93-1.24)** | 0.5 (0.18-1.65) | 0.533 (0.419-0.646) |

AHI=apnea-hypopnea index, BMI=body mass index, NC=neck circumference, PPV=positive predictive value, NPV=negative predictive value, LR+=positive likelihood ratio; LR-=negative likelihood ratio, AUC=area under the receiver operating characteristic (ROC) curve

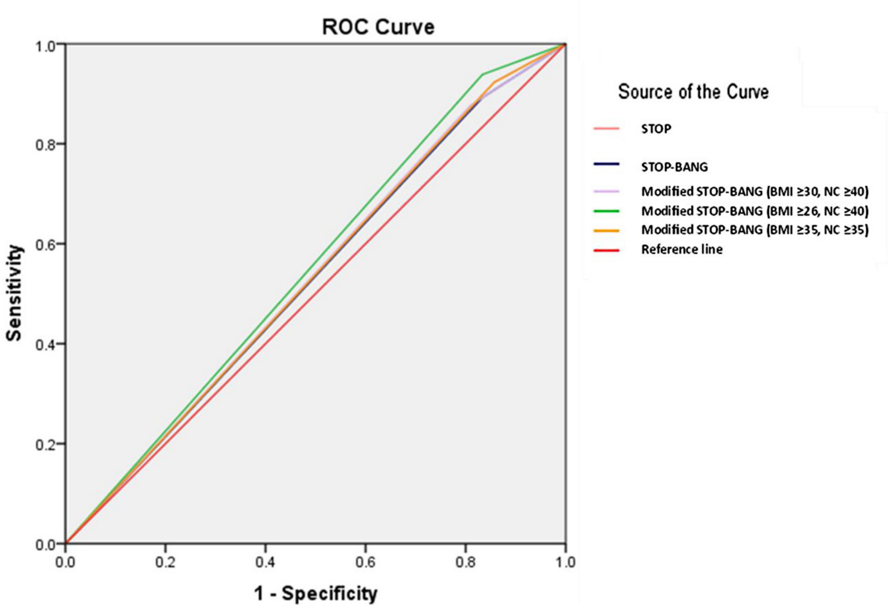
BANG with BMI ≥30 and NC ≥40, 89.4% (79.4–95.6), and STOP-BANG, 87.9% (77.5–94.6). For specificity, the highest value was seen in the modified STOP-BANG with BMI ≥30 and NC ≥40, 18.6% (8.4–33.4), followed by STOP-BANG, 16.3% (6.8–30.7), modified STOP-BANG with BMI ≥26 and NC ≥40, 16.3% (6.8–30.7), modified STOP-BANG with BMI ≥ 35 and NC ≥ 35, 14.3% (5.4–28.5), and STOP, 14.0% (5.3–27.9). The highest PPV was observed in the modified STOP-BANG with BMI ≥26 and NC ≥40, 63.3% (50.9–74.7), followed by STOP, 63.0% (51.2–73.6). The highest NPV was observed in the modified STOP-BANG with BMI ≥26 and NC ≥40, 63.6% (30.8–89.1), followed by STOP-BANG, 50.0% (23.0–77.0). All tools demonstrated equal LR+, 1.1 (0.9–1.4). STOP-BANG and the modified STOP-BANG with BMI ≥ 30 and NC ≥ 40 had the lowest LR–, both 0.7 (0.4–1.1). Lastly, the largest AUC was recorded for the modified STOP-BANG with BMI ≥ 26 and NC ≥ 40, 0.553 (0.436–0.669) (Figure 2).

In summary, the modified STOP-BANG (BMI ≥26, NC ≥ 40) had the highest sensitivity for both AHI cutoffs. The STOP-BANG had the highest specificity at AHI ≥5, while the modified STOP-BANG (BMI ≥30, NC ≥40) demonstrated the highest specificity at AHI ≥15.

## Discussion

STOP and STOP-BANG are widely validated tools for OSA screening, but most studies have utilized them in Western populations with original cutoffs (BMI ≥35 kg/m$^2$, NC ≥40 cm). These thresholds may not suit Asian populations, who often develop OSA at lower BMI and NC values. While previous studies have explored modified BMI cutoffs in the Asian population, our study aimed to evaluate modifications of both BMI and neck circumference in Thai OSA patients for more comprehensive diagnostic accuracy within this specific population.

Our findings demonstrated that the modified STOP-BANG using a BMI cutoff of ≥26 kg/m$^2$ and NC ≥40 cm yielded the highest sensitivity at both AHI thresholds (≥5 and ≥15), with a sensitivity of 93.9% and 93.9%, respectively. These findings align with previous research by Ong et al., which reported that lowering the BMI cutoff to ≥ 26 kg/m$^2$ improved sensitivity in Asian populations with moderate to



AHI=Apnea-Hypopnea Index, BMI=Body Mass Index, NC=Neck Circumference

**Figure 2** The Receiver Operating Characteristic (ROC) curve of the STOP and STOP-BANG screening tools at various BMI and neck circumference thresholds for AHI ≥15. Among the models, modified STOP-BANG BMI ≥26, NC ≥40 (green line) exhibited the largest area under the ROC curve.

severe OSA, from 91% in the original STOP-BANG to 94%[11]. Some studies have proposed using a BMI cutoff of 26 to define obesity in Asian people[12]. Other studies have reported different BMI cutoffs for OSA screening. For example, BMI cutoffs of 25 kg/m$^2$ for the Thai population[8] and 28 kg/m$^2$ for Chinese patients have been shown to significantly improve sensitivity without substantially compromising specificity[13]. Asian individuals may develop OSA and related health problems even at lower BMI levels[14]. This difference is thought to be largely anatomical, as Asian people often exhibit distinct craniofacial and soft tissue characteristics that increase the risk of upper airway obstruction during sleep, independent of body weight. These features include a longer soft palate, a lower position of the tongue base, greater craniocervical extension, as well as increased tongue size, reduced lung volume, and narrower craniofacial structures, all of which contribute to upper airway collapsibility during sleep[15,16]. However, whether lowering the BMI threshold meaningfully enhances the clinical utility of the STOP-BANG tool remains debatable, as the gain in sensitivity is often accompanied by a decrease in specificity.

Interestingly, the modified NC ≥35 cm showed higher sensitivity compared to the original STOP-BANG at both thresholds of AHI. Our result is consistent with several previous findings. For Thai individuals, an NC cutoff of 36 cm was found to be optimal[8]. Similarly, a study on South Korean patients proposed an NC threshold of 36.3 cm[17]. Loh et al. proposed lowering the NC cutoff to 39 cm for males and 35 cm for females in Asian populations to improve sensitivity[18]. However, Ong et al. reported that changing the neck circumference cutoff did not significantly impact the sensitivity or predictive accuracy of the questionnaire[11].

Therefore, our findings suggest that in certain populations, such as Thais, even small adjustments to NC thresholds may enhance screening performance. This highlights the importance of considering population-specific body measurements to improve the accuracy of OSA screening tools in future research.

While sensitivity is crucial for identifying most individuals with OSA, specificity and predictive values are also important for minimizing false positives. At AHI ≥5, the standard STOP-BANG questionnaire showed the highest specificity (54.5%) among all tools, meaning it was better at correctly identifying individuals without OSA. This supports findings from Chung et al., who designed STOP-BANG to improve both the sensitivity and specificity by including physical measurements[10]. However, when looking at AHI ≥15, which represents moderate-to-severe OSA, the specificity of all the tools dropped significantly. The highest specificity at this level was seen in the modified STOP-BANG (BMI ≥30, NC ≥40) at just 18.6%, followed by the standard STOP-BANG and other modified versions. This drop may suggest that using body size and neck circumference alone is less effective in distinguishing the more severe cases, possibly because individuals with and without OSA at this level may share similar physical features[19,20].

In terms of predictive performance, PPV, which reflects the probability that individuals with a positive screen truly have OSA, the highest PPV was observed in STOP-BANG (94.6%), closely followed by STOP (94.0%). Conversely, NPV, the probability that individuals with a negative result are truly free of OSA, was highest in the modified STOP-BANG tools with adjusted BMI and NC, particularly BMI ≥35, NC ≥35, and BMI ≥ 26, NC ≥40 (both 45.5%). Although modest, these values suggest slightly better performance in ruling out OSA at lower thresholds in certain subgroups, such as Thai patients with smaller body frames. Both PPV and NPV at AHI ≥15 were highest in modified STOP-BANG (BMI ≥26, NC ≥40) (63.3% and 63.6%, respectively), further supporting its balanced performance in a population-specific context.

The likelihood ratio analysis further illustrates the clinical role of these tools. At AHI ≥5, LR+ values were low (1.7–2.0), indicating that a positive result only slightly increases the probability of OSA, while LR– values were small (0.1–0.2), showing that a negative result greatly reduces the likelihood of disease. At AHI ≥15, LR+ values were close to 1.0 across all tools, suggesting little ability to confirm moderate-to-severe OSA, whereas LR– values (0.4–0.7) lowered the probability of OSA only to a limited extent. These findings suggest that STOP, STOP-BANG, and its modifications might be more useful for ruling out OSA at lower thresholds than for confirming diagnosis, reinforcing their role as preliminary screening tools rather than definitive diagnostic tests.

Although the modified STOP-BANG with BMI ≥26 and NC ≥40 achieved the highest sensitivity and NPV for AHI ≥15, it demonstrated relatively low specificity. Low specificity increases the likelihood of false positives, meaning that individuals without clinically significant OSA may nevertheless be referred for polysomnography. Such over-referral could burden healthcare systems by straining limited diagnostic resources, prolonging wait times, and increasing costs, especially in countries where sleep laboratories and trained personnel are scarce. Over-referral may also lead to patient anxiety, unnecessary follow-up, and inefficient use of healthcare resources.

Population characteristics, such as referral bias in sleep clinics and the prevalence of OSA in the study sample, likely contributed to the variations observed compared with the previous literature. For instance, our STOP questionnaire showed higher sensitivity (93.1%) but lower specificity (45.5%) at AHI ≥ 5 compared to the study by Chung et al., who reported 65.6% sensitivity and 60% specificity [9]. These variations underscore the importance of adjusting BMI and

NC cutoffs based on population characteristics. Additional tools, such as body fat distribution (e.g., apple-shaped body type), may further enhance screening performance. Sangkum et al. demonstrated that incorporating body type into the STOP-BANG improved specificity by reducing false positives[21].

This study's findings are consistent with prior Asian validation studies, which generally show high sensitivity but low specificity at standard STOP-Bang cutoffs, leading to proposals for lower BMI and NC thresholds in Asian populations. In contrast, Western cohorts appear to perform adequately with the original cutoffs (BMI ≥35 kg/m$^2$, NC ≥40 cm)[22,23]. For example, in a U.S. study of midlife women, a STOP-Bang score ≥ 3 yielded a sensitivity of 77% and a specificity of 45% for detecting moderate-to-severe OSA (AHI ≥ 15), which is comparable to the trade-offs observed in our cohort[24]. Similarly, in Greek patients, STOP-Bang demonstrated strong diagnostic accuracy across multiple cutoffs, with a specificity as high as 92.9% at higher thresholds, contrasting with the lower specificity observed in our population[25]. Importantly, evidence also suggests that the optimal BMI threshold for predicting moderate-to-severe and severe OSA is 27.5 kg/m$^2$ in Chinese and Indian patients, compared with 35 kg/m$^2$ in Malay and Caucasian patients[26]. These differences highlight the influence of anthropometric and craniofacial factors, supporting the need to adapt BMI and NC cutoffs to Asian populations to optimize screening performance.

While the tools are valuable for identifying most patients with OSA in high-prevalence or high-risk populations, clinicians must balance this against the risk of false positives in lower-prevalence settings. These tools should therefore be regarded as preliminary screening instruments rather than definitive diagnostic tests, with results interpreted alongside clinical judgment, symptom burden, and other risk factors. In real-world dental clinic settings, where patients often present without prior PSG results, prioritizing sensitivity is particularly important to avoid missed OSA cases when severity is unknown at baseline. The modified STOP-BANG with BMI ≥26 and NC ≥40 may thus be more suitable in this context, as its higher sensitivity enhances case detection. Although this comes at the expense of reduced specificity, the trade-off is acceptable in a screening environment, since a definitive diagnosis still requires PSG confirmation.

However, our study had several limitations. The sample size of 112 participants was sufficient for overall accuracy estimates but may still have limited statistical power, particularly given the predominance of male participants. This gender imbalance and the modest sample size made subgroup analyses (e.g., by sex or BMI) infeasible, as dividing the cohort into smaller groups would have produced unstable estimates. Future studies with larger and more diverse populations are therefore needed to explore these subgroup differences. All participants were recruited from a single dental sleep clinic, which introduces selection bias and limits external validity, as this population, patients referred for suspected OSA, may not represent the broader community or primary care settings. Consequently, our modified thresholds, derived from a higher pretest probability population, may have limited applicability in lower-prevalence and more heterogeneous groups. Applying these thresholds outside specialist settings could increase false positives and over-referrals; therefore, further validation in broader, community-based populations is warranted before widespread use.

In addition, recall or reporting bias from questionnaire responses cannot be excluded, since participants may have under- or over-reported symptoms such as snoring or witnessed apneas, which rely heavily on memory and bed-partner observations. Although our dataset was collected between 2007 and 2021, during which the American Academy of Sleep Medicine (AASM) updated its hypopnea scoring rules, all studies were conducted as attended Type

I polysomnography in accredited sleep laboratories. Thus, uniform scoring standards were applied within each practice according to AASM guidelines. Nevertheless, potential variability in hypopnea definitions (≥3% desaturation or arousal vs. ≥4% desaturation) cannot be entirely ruled out, which may have influenced absolute AHI values. Importantly, the diagnostic thresholds for OSA severity (mild: 5–14, moderate: 15–29, severe: ≥30) remained unchanged throughout this period.

Finally, the low specificity observed in all the tools, particularly at AHI ≥ 15, raises the possibility of over-referral, which could strain healthcare resources if applied widely in settings with limited access to polysomnography. While the modified STOP-BANG with BMI ≥26 and NC ≥40 demonstrated high sensitivity, this must be balanced against its low specificity. Future research should validate these modified cutoffs in larger, more diverse populations, including more female participants and individuals from community or primary care settings, to establish generalizability and assess their practical value for screening in Thailand.

## Conclusion

This study highlights that the modified STOP-BANG questionnaire, using BMI ≥26 kg/m$^2$ and neck circumference ≥40 cm, achieved the highest sensitivity for detecting OSA among adults in Southern Thailand. These findings suggest that population-specific adjustments improve screening performance and support the use of tailored tools for early OSA detection in regional clinical settings.

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