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RESEARCH

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# Anthropometric screening approach for obstructive sleep apnea in Japanese men: development and validation of the ABC scale

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## Abstract

**Background** The existing screening tools for the detection of moderate and severe obstructive sleep apnea (OSA) are tailored to Western individuals. The aim of this study was to formulate and validate a simple anthropometric tool for OSA screening in a Japanese male population by incorporating objective indicators obtained during routine medical checkups.

**Methods** In total, 443 Japanese men, who were suspected of having OSA and visited our sleep disorder clinic from 2009 to 2012, were retrospectively divided into two groups (development group [DG], $n = 206$; validation group [VG], $n = 237$). In the DG, OSA was defined as an apnea–hypopnea index of ≥ 15 events/h. Data regarding clinical and anthropometric variables (age, body mass index [BMI], neck circumference [NC], waist circumference [WC]) were obtained. For parameters that were associated with OSA on simple logistic regression analysis, cutoff values were calculated with receiver operating characteristic curves to create a new screening tool. The utility of the tool was evaluated in the VG and compared to that of the modified Berlin questionnaire (mBQ) for OSA.

**Results** Age (odds ratio [OR] = 1.033, $p = 0.002$), BMI (OR = 1.231, $p < 0.001$), NC (OR = 1.327, $p < 0.001$), and WC (OR = 1.083, $p < 0.001$) were significant risk factors for OSA in the DG. Cutoff values for the prediction of OSA were age: ≥ 46.5 years, BMI: ≥ 25.45 kg/m$^2$, NC: ≥ 38.35 cm, and WC: ≥ 90.75 cm. Our screening tool, incorporating age, BMI, and WC, yielded 70.1% sensitivity (mBQ: 85.4%) and 66.0% specificity (mBQ: 35.0%) in the VG.

**Conclusions** OSA screening in Japanese men has been conducted only in limited settings such as sleep clinics. The study findings support the implementation of screening in medical checkups using objective indices to enable early detection and treatment of OSA.

**Keywords** Obstructive sleep apnea, Age, Body mass index, Neck circumference, Waist circumference, Screening

## Background

Obstructive sleep apnea (OSA) is a common disorder characterized by intermittent partial and complete obstruction of the upper airway, associated with hypoxemia and disturbed sleep. Frequent respiratory events during sleep, including apnea and hypopnea, reportedly increase the risks of cardiovascular and cerebrovascular diseases (Nakayama-Ashida et al. 2008). Furthermore, sleep disruption due to frequent awakenings associated with apnea or hypopnea results in daytime sleepiness and decreased concentration, leading to a high risk of traffic

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accidents (Young et al. 1997). Considering these health risks, various treatments that suppress the collapse of the upper airway have been indicated, particularly for patients with moderate-to-severe OSA with an apnea–hypopnea index (AHI) of ≥ 15 events/h (Akashiba et al. 2022).

In an epidemiological study conducted in Japan in 2008, 322 consecutive male workers (aged 23–59 years) underwent portable monitoring for measurement of respiratory disturbance and actigraphic recording for estimation of total sleep time, and 22.3% of participants experiencing ≥ 15 respiratory disturbance events/h (Nakayama-Ashida et al. 2008). According to these figures, approximately 9 million Japanese may have moderate-to-severe OSA (Benjafield et al. 2019). However, the number of patients who use continuous positive airway pressure is only 0.5 million, with several undiagnosed and untreated cases (Statistics by social and medical affairs 2023).

OSA screening tools, such as the Berlin questionnaire (BQ) (Netzer et al. 1999) and STOP-BANG questionnaire (SBQ) (Chung et al. 2008), have been widely used. To date, these questionnaires have been proactively administered to patients visiting sleep disorder-specific medical institutes; however, they are not commonly used in general practice or during medical checkups. In addition, the questionnaires were designed with a focus on Western populations. Therefore, new screening tools that are widely available to the general population, including Asian populations, need to be established.

Subjective symptoms, such as sleepiness and fatigue, and objective symptoms, such as apnea and habitual snoring witnessed by family members, have been used as core items in the abovementioned screening questionnaires. However, because of certain Japanese sleeping habits, such as spouses sleeping in different bedrooms, and a long single life with late marriage, particularly among men, a considerable number of individuals in the Japanese population may be unaware that they snore or experience apneic events while asleep. Obesity is also a major risk factor for OSA; the World Health Organization defines obesity as body mass index (BMI) of ≥ 30 kg/$m^2$ and the cutoff BMI values were set at 35 kg/$m^2$ in the SBQ and 30 kg/$m^2$ in the BQ. However, the Japanese Society for the Study of Obesity defines obesity as BMI of ≥ 25 kg/$m^2$ (Examination Committee of Criteria for 'Obesity Disease' in Japan, Japan Society for the Study of Obesity 2002), and the average BMI of Japanese patients with OSA is in the range of 25–28 kg/$m^2$ (Nakayama-Ashida et al. 2008; Kim et al. 2018), which is clearly lower than that of Western patients. In addition, rather than using neck circumference (NC), which is an important parameter for the prediction of OSA in the SBQ, waist circumference (WC) is routinely measured at medical checkups and in general practice in Japan (Joshipura et al. 2016). Reportedly, not only NC (Kim et al. 2018; Onat et al. 2009) but also WC is related to the presence of OSA (Tom et al. 2018). In addition, in recent years, simple OSA screening attempts using smart watches and smartphone applications have been reported, but careful interpretation is required until their clinical use is validated (Zhang et al. 2021).

Given the above, the possibility of establishing a screening tool for OSA with objective indicators that do not rely on witnessed snoring and apnea needs to be ascertained for the Japanese population and whether WC, a commonly used anthropometric measure, is a viable alternative to NC for such screening. The purpose of this study was to develop an objective screening tool for the accurate prediction of moderate-to-severe OSA in Japanese men using age, BMI, and WC and to validate the new tool by comparing its accuracy to that of the BQ.

## Methods

### Participants

Consecutive Japanese patients who visited the Yoyogi Sleep Disorder Center from November 2009 to January 2012 with suspected OSA (based on information about habitual snoring and/or episodes of apnea witnessed by their family members, or excessive daily sleepiness) were eligible to participate in the study. Among them, patients who had already undergone treatment for OSA, female patients (because of sex differences in the prevalence of OSA (Dancey et al. 2003; Yukawa et al. 2009; Rowley et al. 1985)), and patients without polysomnography (PSG) data were excluded (Fig. 1). Participants were retrospectively divided into two groups: development group (DG) and validation group (VG). The DG consisted of patients who visited the outpatient clinic from November 2009 to August 2010; the VG consisted of patients who underwent PSG from September 2010 to January 2012. At their first visit, participants provided written informed consent for the use of their clinical variables and PSG data for research purposes. This study was conducted after obtaining approval from the institutional review board of the Institute of Neuropsychiatry, Japan (approval number: 182).

### Assessment of anthropometric variables and interviews

At the first visit, we measured patients' height, body weight, NC, and WC. NC was measured at the cricothyroid level with patients in the upright position; WC was measured at the height of the umbilicus, at the end of expiration, with patients in the standing position. In addition, patients were asked to complete the Japanese version of the Epworth Sleepiness Scale (JESS)

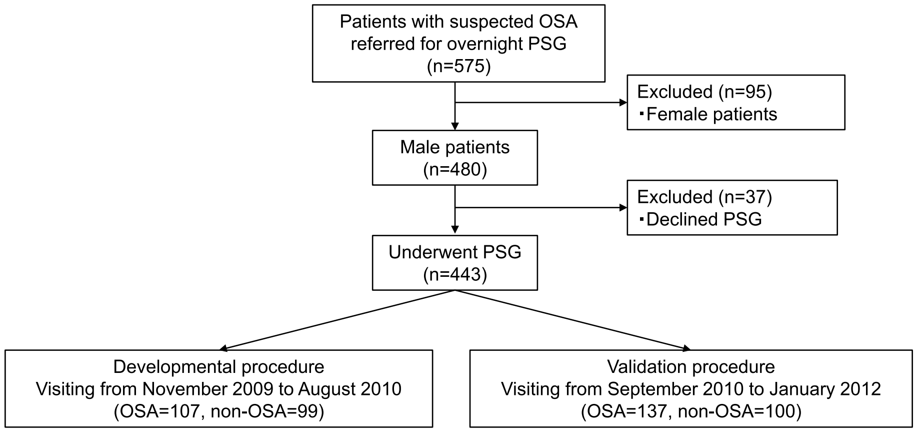


**Fig. 1** Flow diagram of study design. The study sample population comprised Japanese patients with suspected OSA who visited Yoyogi Sleep Disorders Center from November 2009 to January 2012. Patients already treated for OSA, female patients, and patients without PSG data were excluded. OSA, obstructive sleep apnea; PSG, polysomnography

(Takegami et al. 2009) and to report the presence/absence of comorbidities possibly associated with OSA.

## Sleep study

Nocturnal PSG was performed using the Alice 5 (Respironics, Inc. Murrysville, PA, USA) or Comet (Astro-Med, Inc., West Warwick, RI, USA) systems. These consisted of electroencephalography (EEG), electrooculography, electromyography of the mentalis muscle and leg surface, nasal airflow, respiratory movements of the chest and abdomen, snoring sounds, percutaneous arterial oxygen saturation, body position, and electrocardiography.

PSG data were analyzed with manual scoring for every 30-s epoch according to the criteria developed by Rechtschaffen and Kales (R&K) (Hori et al. 2001), and EEG arousals were scored according to the American Sleep Disorders Association guidelines (EEG arousals: scoring rules and examples: a preliminary report from the Sleep Disorders Atlas Task Force of the American Sleep Disorders Association 1992). Apnea was defined as the complete cessation of airflow for at least 10 s. Hypopnea was defined as a substantial (> 50%) reduction in airflow for at least 10 s or moderate reduction in airflow for at least 10 s associated with EEG arousals and/or oxygen desaturation (≥ 3%) (Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research 1999). AHI was defined as the total number of apnea and hypopnea episodes per hour of sleep.

## Statistical approaches for the development and validation of the screening tool

Continuous variables are displayed as mean ± standard deviation and categorical variables as frequency and percentage.

In the DG, patients with OSA were defined as those with an AHI of ≥ 15 events/h, and those with an AHI of < 15 events/h were defined as "others." We compared the clinical variables between patients with OSA and others using the Mann–Whitney U-test for continuous variables and the chi-square test for categorical variables. Simple logistic regression analysis was performed to assess the association of each parameter with the presence of moderate-to-severe OSA (Kang et al. 2014).

To provide a predictive cutoff value to identify patients with moderate-to-severe OSA, receiver operating characteristic (ROC) curves were constructed for each parameter that was significant in the logistic regression analysis, and the optimal cutoff values were determined with the ROC curve analyses. Those cutoff values were used to develop a new screening tool in which each item was assigned one point when it exceeded the cutoff value. ROC curves were constructed for the total score obtained with the new screening tool, and the ability of this method to predict the presence of moderate-to-severe OSA was evaluated according to its sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) in the DG.

The predictive abilities of the new screening tool were validated in the VG, and its performance was compared with that of the BQ. The original and modified BQ (Kojima et al. 2007) (using BMI ≥ 25 kg/m$^2$ instead

**Table 1** Comparisons of clinical and anthropometric variables between the patients in the two phases

| | All $n=443$ | Development phase $n=206$ | Validation phase $n=237$ | *p*-value |
|---|---|---|---|---|
| Age (years) | 48.8 ± 12.9 | 49.8 ± 13.7 | 47.9 ± 12.1 | 0.245 |
| Body mass index (kg/m$^2$) | 26.2 ± 5.1 | 26.0 ± 4.9 | 26.4 ± 5.2 | 0.537 |
| Neck circumference (cm) | 39.5 ± 3.2 | 39.4 ± 3.1 | 39.6 ± 3.3 | 0.498 |
| Waist circumference (cm) | 92.2 ± 11.6 | 91.7 ± 11.5 | 92.7 ± 11.7 | 0.333 |
| Apnea–hypopnea index (episodes/h) | 26.4 ± 25.0 | 24.5 ± 23.8 | 28.0 ± 25.9 | 0.130 |
| Epworth Sleepiness Scale (score) | 11.4 ± 4.9 | 11.0 ± 4.5 | 11.7 ± 5.1 | 0.119 |
| Hypertension (%) | 211 (47.6) | 88 (42.7) | 123 (51.9) | 0.054 |
| Cardiovascular disorder (%) | 10 (2.3) | 5 (2.4) | 5 (2.1) | 0.527 |
| Diabetes mellitus (%) | 48 (10.8) | 23 (11.2) | 25 (10.5) | 0.777 |
| Heart failure (%) | 12 (2.7) | 7 (3.4) | 5 (2.1) | 0.403 |

Continuous variables are presented as mean ± standard deviation, and the Mann–Whitney U-test was used for comparisons of these variables. Categorical variables are presented as frequency and percentage, and comparisons were made using the chi-square test

**Table 2** Comparison of clinical and anthropometric variables between groups during the development phase

| | AHI ≥ 15 $n=99$ (48.1%) | | AHI < 15 $n=107$ (51.9%) | | *p*-value |
|---|---|---|---|---|---|
| | **mean ± SD or n (%)** | **range** | **mean ± SD or n (%)** | **range** | |
| Age (years) | 52.6 ± 13.5 | 25–86 | 46.7 ± 13.3 | 23–77 | 0.003 |
| Body mass index (kg/m$^2$) | 27.7 ± 5.7 | 15.2–57.5 | 24.3 ± 3.0 | 18.4–36.4 | < 0.001 |
| Neck circumference (cm) | 40.4 ± 3.4 | 34–51 | 38.2 ± 2.4 | 31.5–45 | < 0.001 |
| Waist circumference (cm) | 95.4 ± 12.7 | 67–162 | 87.5 ± 8.3 | 67–120 | < 0.001 |
| Epworth Sleepiness Scale (score) | 11.4 ± 4.2 | 3–23 | 10.6 ± 4.8 | 0–22 | 0.258 |
| Apnea–hypopnea index (events/h) | 40.9 ± 22.8 | 15.1–107.7 | 6.7 ± 4.1 | 0.2–14.6 | < 0.001 |
| Hypertension | 48 (48.5) | | 40 (37.4) | | 0.518 |
| Cardiovascular disorder | 3 (3.0) | | 2 (1.9) | | 0.542 |
| Diabetes mellitus | 15 (15.2) | | 8 (7.5) | | 0.154 |
| Heart failure | 5 (5.1) | | 2 (1.9) | | 0.247 |

The Mann–Whitney U-test was used for comparison of continuous variables between individuals with and those without OSA. The values are presented as mean ± SD. Categorical variables are presented as frequency and percentage, and comparisons were made using the chi-square test. *OSA* obstructive sleep apnea, *SD* standard deviation

of ≥ 30 kg/m$^2$) were both completed at each participant's first visit. Data were analyzed using SPSS version 27 (SPSS Japan, Inc., Tokyo, Japan), and *p*-values of < 0.05 were considered statistically significant.

## Results

Table 1 summarizes the clinical and anthropometric variables of the 443 male patients (age, 48.8 ± 12.9 years; BMI, 26.2 ± 5.1 kg/m$^2$) in this study. The DG and VG did not significantly differ in terms of age, BMI, NC, WC, AHI, JESS score, or the proportions of patients with hypertension, cardiovascular diseases, diabetes mellitus, or heart failure (all $p > 0.05$).

In the DG, significant differences were noted in age ($p = 0.003$), BMI ($p < 0.001$), NC ($p < 0.001$), and WC ($p < 0.001$) between patients with OSA (AHI, ≥ 15 events/h) and other participants (AHI, < 15 events/h). However, those subgroups did not significantly differ in terms of JESS scores or the proportions of patients with hypertension, cardiovascular disease, diabetes mellitus, or heart failure (Table 2).

**Table 3** Associations of age, BMI, neck circumference, and waist circumference with having OSA

| | Univariate (continuous variable) | |
|---|---|---|
| | **OR (95% CI)** | ***p*-value** |
| Age | 1.033 (1.012–1.056) | 0.002 |
| BMI | 1.231 (1.128–1.343) | < 0.001 |
| NC | 1.327 (1.180–1.493) | < 0.001 |
| WC | 1.083 (1.048–1.120) | < 0.001 |

Odds ratios were calculated by using logistic regression analysis

*BMI* body mass index, *NC* neck circumference, *WC* waist circumference, *OR* odds ratio, *CI* confidence interval

Logistic regression analysis revealed that age, BMI, NC, and WC were significantly associated with having OSA (Table 3). Results of the ROC curve analyses for each parameter are plotted in Fig. 2, and the analysis yielded the following cutoff values for having an AHI of ≥ 15 events/h: age ≥ 46.5 years, BMI ≥ 25.45 kg/m$^2$, NC ≥ 38.35 cm, and WC ≥ 90.75 cm. The sensitivity and

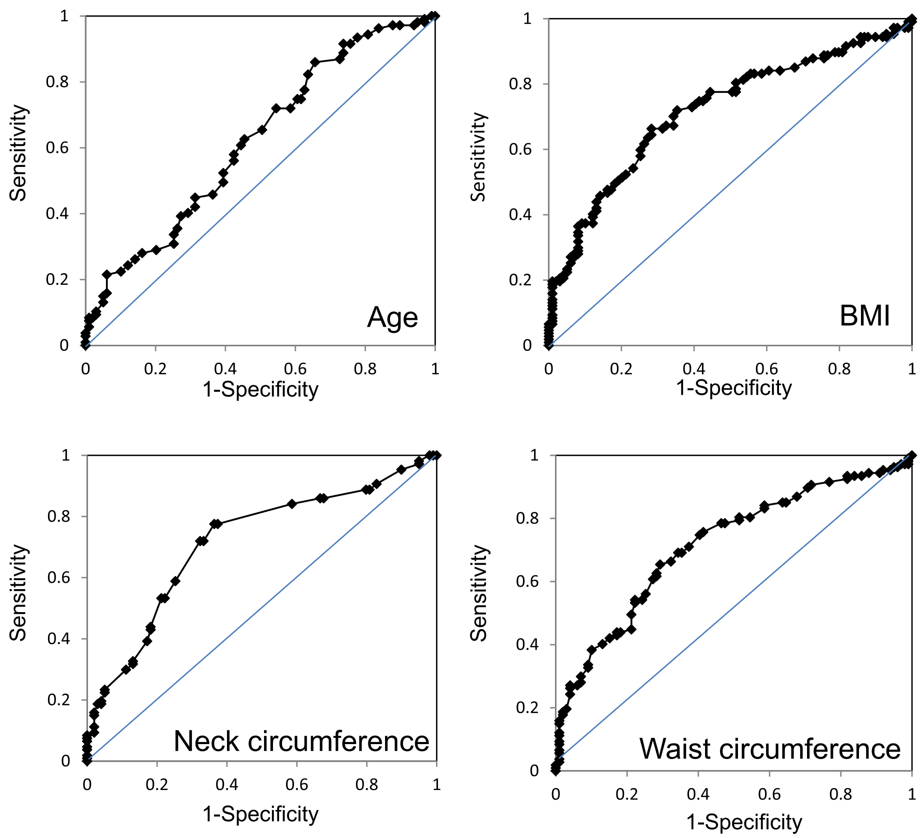


**Fig. 2** ROC for age, BMI, neck circumference, and waist circumference. BMI, body mass index; ROC, receiver operating characteristic

**Table 4** Cutoff values for having AHI ≥ 15 events/h

| | Cutoff | SEN | SPEC | PPV | NPV | LR (+) | LR (-) | AUC |
|---|---|---|---|---|---|---|---|---|
| Age (years) | 46.5 | 62.6 | 54.5 | 59.8 | 57.4 | 1.38 | 0.69 | 0.619 |
| BMI (kg/m$^2$) | 25.45 | 72.0 | 64.6 | 68.8 | 68.1 | 2.04 | 0.43 | 0.718 |
| NC (cm) | 38.35 | 77.6 | 63.6 | 69.7 | 72.4 | 2.13 | 0.35 | 0.716 |
| WC (cm) | 90.75 | 69.2 | 65.7 | 68.5 | 66.3 | 2.01 | 0.47 | 0.717 |

*AHI* apnea–hypopnea index, *BMI* body mass index, *NC* neck circumference, *WC* waist circumference, *SEN* sensitivity, *SPEC* specificity, *PPV* positive predictive value, *NPV* negative predictive value, LR (+): positive likelihood ratio, LR (-): negative likelihood ratio, AUC: area under the receiver operating characteristic curve

specificity values for each of these variables are presented in Table 4. After categorizing age, BMI, NC, and WC using these cutoff values, logistic regression analysis was performed to calculate odds ratios (Table 5). We decided to create the new screening tool by adopting age, BMI, and WC but not NC, as the latter is not measured routinely in Japan. We named the tool the "ABC" scale, as it incorporates Age, BMI, and WC. According to this scale, a score of 1 was allocated for each cutoff value met. The clinical score was calculated as follows:

$$\text{ABC scale (AHI} \geq 15\text{ events/h)} = (\text{age} \geq 46.5\text{ years}) + (\text{BMI} \geq 25.45\text{kg/m}^2) + (\text{WC} \geq 90.75\text{cm})$$

**Table 5** Associations of age, BMI, neck circumference, and waist circumference with having OSA after categorization

| | Univariate (after categorization) | |
|---|---|---|
| | OR (95% CI) | *p*-value |
| Age (46.5 years) | 2.010 (1.152–3.507) | 0.010 |
| BMI (25.45kg/m$^2$) | 4.693 (2.602–8.464) | < 0.001 |
| NC (38.35 cm) | 6.052 (3.283–11.156) | < 0.001 |
| WC (90.75 cm) | 4.287 (2.392–7.683) | < 0.001 |

Odds ratios were calculated using simple logistic regression analysis

*BMI* body mass index, *NC* neck circumference, *WC* waist circumference, *OR* odds ratio, *CI* confidence interval

In the DG, when a patient had an ABC scale score of ≥ 2, the sensitivity, specificity, PPV, NPV, positive likelihood ratio, negative likelihood ratio, and area under the ROC curve were 69.2%, 72.7%, 72.5%, 68.3%, 2.45, and 0.430, and 0.678, respectively.

The utilities of the ABC scale and the original and modified BQs as screening tools for OSA in the VG are summarized in Table 6. For the prediction of OSA, 2 points or more on the ABC scale yielded a 70.1% sensitivity, 66.0% specificity, 73.8% PPV, 61.7% NPV, 2.061 positive likelihood ratio, and 0.453 negative likelihood ratio. Conversely, the original BQ yielded a 75.2% sensitivity, 41.0% specificity, 63.6% PPV, and 54.7% NPV, and the modified BQ yielded an 85.4% sensitivity, 35.0% specificity, 64.3% PPV, and 63.6% NPV.

A patient was deemed to have OSA according to the ABC scale if they met two or more of the following criteria: age ≥ 47 years, BMI ≥ 25.0 kg/m$^2$, and WC ≥ 89.8 cm. A patient was deemed to have OSA according to age, BMI, and NC if they met two or more of the following criteria: age ≥ 47 years, BMI ≥ 25.0 kg/m$^2$, and NC ≥ 38.4 cm. The cutoff for BMI in the original BQ is ≥ 30 kg/m$^2$; that in the modified BQ is ≥ 25 kg/m$^2$. OSA: obstructive sleep apnea; BQ: Berlin questionnaire; ABC scale: the combination of Age, BMI and waist Circumference; BMI, body mass index; AHI: apnea–hypopnea index; PPV: positive predictive value; NPV: negative predictive value; NC, neck circumference.

## Discussion

The aim of this study was to formulate and validate a simple anthropometric screening tool to detect moderate-to-severe OSA in a Japanese male population. In the DG, the cutoff values for prediction of moderate-to-severe OSA were age ≥ 46.5 years, BMI ≥ 25.45 kg/m$^2$, NC ≥ 38.35 cm, and WC ≥ 90.75 cm. Using these objective parameters, we formulated an OSA screening tool, namely, the ABC scale (incorporating age, BMI, and WC). The validation analysis revealed that the ABC scale was sufficient as a screening tool for OSA (sensitivity, 70% and specificity, 66%) in this population.

**Table 6** OSA screening utility of the original and modified BQs, the ABC scale and the combination of age, BMI and neck circumference

| | | Original BQ | Modified BQ | ABC scale | Age, BMI, NC |
|---|---|---|---|---|---|
| AHI ≥ 15 | Sensitivity | 75.2% | 85.4% | 70.1% | 75.2% |
| | Specificity | 41.0% | 35.0% | 66.0% | 60.0% |
| | PPV | 63.6% | 64.3% | 73.8% | 72.0% |
| | NPV | 54.7% | 63.6% | 61.7% | 63.8% |

The prevalence of OSA is well known to increase with age, and it is most prevalent in middle-aged and older individuals. Physiological changes associated with aging, such as upper airway collapsibility (Edwards et al. 2014), a decreased vital capacity and/or an increased functional residual capacity (Mittman et al. 1965), and a low position of the pharynx (Yamashiro and Kryger 2012), are all risk factors for OSA. However, although pharyngeal collapsibility decreases and pharyngeal resistance increases with age, these relationships plateaued from the age of 45 years onward, in one study (Eikermann et al. 2007). Similarly, the cutoff age for prediction of OSA in the SBQ is set at 50 years (Chung et al. 2008). Therefore, the cutoff age of 46.5 years in our ABC scale seems reasonable in the general population.

OSA and BMI are highly correlated, and in a study on the Turkish adult population, higher BMI values were deemed significant risk factors for OSA development (Soylu et al. 2012). The reported cutoff BMI for moderate sleep-disordered breathing in Americans is 32.3 kg/m$^2$ (Young et al. 2005). However, in a Japanese study, a cutoff BMI of 25 kg/m$^2$ was the point at which the prevalence of sleep-disordered breathing increased (Matsumoto et al. 2020). Obesity is defined as BMI of ≥ 30 kg/m$^2$ in Westerners but as BMI ≥ 25 kg/m$^2$ in the Japanese population (Examination Committee of Criteria for 'Obesity Disease' in Japan, Japan Society for the Study of Obesity 2002). Therefore, as the cutoff BMI for OSA differs according to ethnicity, a cutoff BMI must be determined for each country. The cutoff BMI of 25.45 kg/m$^2$ in this study seems reasonable.

WC is negatively associated with respiratory function during sleep, and the increase in WC is likely to exacerbate apnea. In many studies of adult populations, higher WC and NC values were deemed significant risk factors for OSA development (Ahbab et al. 2013; Cizza et al. 2014), whereas WC correlated better with OSA severity than did NC in some other studies (Tom et al. 2018; Kang et al. 2014; Borges et al. 2013). NC is a strong predictor of OSA (Kim et al. 2018; Onat et al. 2009) and is used in the SBQ, as NC reflects the volume of pharyngeal soft tissue and fat (Li et al. 2012). However, NC is not routinely measured either in general practice or in medical checkups (Joshipura et al. 2016). The correlation coefficient between NC and WC in this present study was 0.816 ($p < 0.001$) for the DG and 0.780 ($p < 0.001$) for the VG, indicating strong positive correlations. Considering this, we also compared the screening ability of a tool incorporating age, BMI, and NC to that of our ABC scale. We found that the scale incorporating NC had a slightly higher sensitivity than the ABC scale (75.2% vs. 70.1%) but a slightly lower specificity (60.0% vs. 66.0%). This result suggests that the screening ability of the ABC scale is not inferior to that of the tool incorporating NC.

As for the sensitivity and specificity of the ABC scale for prediction of moderate-to-severe OSA, no significant differences were observed between the values obtained when one point was assigned for cutoff values of age, BMI, NC, and WC, respectively, and those obtained with weighting according to ORs derived from logistic regression analysis. Taking this into consideration, we adopted the ABC scale, more convenient method. The validation analysis revealed that the ABC scale (incorporating age, BMI, and WC) was sufficient for the screening of moderate-to-severe OSA in this population.

In the present study, we also compared the validity of the ABC scale with that of the original and modified BQ in terms of screening of moderate-to-severe OSA. We found that the original BQ (using BMI cutoff of $\geq$ 30 kg/m$^2$) yielded fair sensitivity (75.2%) in our Japanese study population, and the mBQ (using BMI cutoff of $\geq$ 25 kg/m$^2$) had higher sensitivity (85.4%). The ABC scale was slightly less sensitive than the original and modified BQ but could be more useful than the BQs, which include many questions on snoring and apnea, and the SBQ, which uses NC, because a considerable number of Japanese people live alone or sleep without bed partners, and NC is rarely measured during medical checkups in Japan.

The present study has several limitations. First, it was conducted in a single sleep disorder clinic, and the prevalence of moderate-to-severe OSA was relatively high because all participants were referred to the clinic with suspected OSA. Therefore, the conclusion that can be drawn from the results is limited to the following: in a highly selected cohort, the anthropometrics were able to identify moderate-to-severe OSA with a sensitivity of 70% and a specificity of 66%. Although the sensitivity of the ABC was almost the same as that of the original BQ and its specificity was higher in this sample, further studies are required to assess the accuracy of the ABC scale as a screening tool for OSA in the general population. Second, this study was conducted only in men because of an insufficient number of women with potential OSA for the analyses. Reportedly, cutoff anthropometric parameter values for prediction of OSA may differ according to sex (Yukawa et al. 2009). Therefore, female-specific cutoff values of both anthropometric parameters and age for prediction of OSA should be established. We aim to investigate this in future research. Third, the older scoring criteria (R&K and American Sleep Disorders Association) were applied to the polysomnographic data obtained from 2009 to 2012, and subsequently, the American Academy of Sleep Medicine scoring criteria have been used starting from December 2012. We cannot exclude the possibility that the change in scoring criteria may have led to some differences in the interpretation of respiratory events.

## Conclusion

We successfully established and validated a simple screening tool, incorporating age, BMI, and WC, for screening of moderate-to-severe OSA in a Japanese male population. This scale yielded almost the same sensitivity as the BQ but a considerably higher specificity. Moreover, this scale may be useful for screening of OSA regardless of whether the individual has cohabitants. Considering that WC measurements are routinely performed during medical checkups, the implementation of this ABC scale will likely promote the early detection of OSA.

### Abbreviations

| | |
|---|---|
| AHI | Apnea–hypopnea index |
| BMI | Body mass index |
| BQ | Berlin questionnaire |
| DG | Development group |
| EEG | Electroencephalography |
| JESS | Japanese version of the Epworth sleepiness scale |
| mBQ | Modified Berlin questionnaire |
| NC | Neck circumference |
| NPV | Negative predictive value |
| OR | Odds ratio |
| OSA | Obstructive sleep apnea |
| PPV | Positive predictive value |
| PSG | Polysomnography |
| R&K | Rechtschaffen and Kales |
| ROC | Receiver operating characteristic |
| SBQ | STOP-BANG questionnaire |
| VG | Validation group |
| WC | Waist circumference |

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This study was performed at the Japan Somnology Center, Institute of Neuropsychiatry, Japan.

### Authors' contributions

All authors contributed to the study conception and design. Data collection was performed by all authors, and material preparation and analysis were performed by TH, KM, NH and YI. The first draft of the manuscript was written by TH, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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### Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

## Declarations

### Ethics approval and consent to participate

This study was conducted after obtaining approval from the institutional review board of the Institute of Neuropsychiatry (approval number: 182). All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all the participants.

**Consent for publication**
Participants provided written informed consent for the use of their clinical variables and polysomnographic data for research purposes.

**Competing interests**
The authors declare no competing interests.

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