The Kushida Index as a screening tool for obstructive sleep apnoea-hypopnoea syndrome

S. Jauhar,[1] R. Orchardson,[2] S. W. Banham,[3] E. Livingston,[4] A. Sherriff[5] and M. F. Lyons[6]

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IN BRIEF

- Outlines the possible role of the dentist in screening for obstructive sleep apnoea-hypopnoea syndrome (OSAHS).
- Assesses the validity of screening for OSAHS using the Kushida Index by dentists in the West of Scotland.

RESEARCH

Objectives To test the validity of the Kushida Index for screening for sleep apnoea in a West of Scotland adult population. **Methods** Specific intra-oral measurements and respiratory polysomnography were carried out on 71 patients in this prospective study. The intra-oral measurements were applied to the Kushida formula to obtain a value for the Kushida Index. This value was compared to the diagnosis obtained using polysomnography in the conventional manner. **Results** The sensitivity of the Kushida Index in this present study was 68% (95% CI 50-81) and the specificity was 71% (95% CI 52-84). The positive predictive value was 71% and the negative predictive value was 67%. The Mallampati score, Epworth sleepiness score and enlargement of the tongue, soft palate or tonsils were not statistically significantly related to a diagnosis of sleep apnoea (p >0.05). **Conclusion** With the limited sensitivity and specificity of the Kushida Index demonstrated in this study, this test cannot be recommended as a screening tool for sleep apnoea in a West of Scotland population.

INTRODUCTION

Obstructive sleep apnoea-hypopnoea syndrome (OSAHS) is a common disorder that affects approximately four percent of the population.[1] It has been associated with increased daytime sleepiness, impairment of cognitive function and changes in mood and personality.[2] It has also been associated with a reduction in quality of life, impaired relationships between spouses and partners, decreased daytime alertness and an increased risk of accidents while driving.[3–8] It has also been reported that there is a five-fold increase in the risk of cardiovascular disease if OSAHS remains untreated.[9]

Unfortunately, one of the troublesome symptoms of OSAHS, snoring, is very common and does not necessarily indicate that a patient has OSAHS. Therefore a distinction should be made between simple uncomplicated snorers and patients with OSAHS. Although dentists have a valuable role to play in the treatment of uncomplicated snorers, patients with OSAHS should be diagnosed by an appropriate physician and treated under their prescription. The current gold standard for the investigation of OSAHS includes clinical examination, assessment of daytime somnolence and an overnight sleep study (polysomnography). Many different screening methods have been used to attempt to reduce the cost and inconvenience of overnight sleep studies, but Pang *et al.* concluded that there needed to be further validation of these methods before widespread use could be recommended.[10] However, one screening method that showed potential, with a sensitivity of 97.6% and a specificity of 100%, was published by Kushida *et al.* in 1997.[11] Bearing in mind that the role of dentists in the management of patients with OSAHS has become more established over the last decade,[12–17] the Kushida Index appears to be a simple screening tool that could be used by dentists in general dental practice to screen those patients with a suspicion of OSAHS.

The idea behind the Kushida Index is that disproportionate craniofacial morphology may form a risk factor for OSAHS and this may be unrelated to obesity. A small, or hypoplastic, mandible will cause a posterior position of the tongue with resultant narrowing of the upper airway and often a high, arched palate. Therefore overjet, inter-molar distance and palatal height were used, together with neck circumference and body mass index (BMI), in a morphometric mathematical model. If the calculation gave a figure of 70 or above, it was considered highly indicative of a patient having OSAHS.

AIMS

The aim of this study was to assess the validity and reliability of the Kushida Index as a screening tool for OSAHS in a West of Scotland population. A secondary aim was to assess whether other factors (Mallampati score, Epworth sleepiness score, enlarged tongue, enlarged soft palate, or obstruction due to tonsil enlargement) were associated with the diagnosis of OSAHS.

METHOD

The Standards for Reporting of Diagnostic Accuracy (STARD) checklist was used in this study.[18] The study protocol was approved by the Glasgow West Local Research Ethics Committee 2. A power calculation was carried out based on data from Kushida's study, with the assumption of finding 95%

[1*]Consultant, Department of Restorative Dentistry, Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow G2 3JZ; [2]Senior Lecturer Oral Biology, Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow G2 3JZ; [3]Consultant, Department of Respiratory Medicine, Gartnavel General Hospital 1053 Great Western Road, Glasgow G12 0YN; [4]Consultant, Department of Respiratory Medicine, Glasgow Royal Infirmary 84 Castle Street, Glasgow, Lanarkshire, G4 0SF; [5]Senior Lecturer in Statistics, Glasgow Dental Hospital and School, 378 Sauchiehall Street, Glasgow G2 3JZ. Faculty of Medicine; [6]Senior Lecturer, Section of Restorative Dentistry, Dundee Dental Hospital and School, Park Place, Dundee DD1 4HN.
*Correspondence to: Mr Sachin Jauhar
Email: sachin.jauhar@ggc.scot.nhs.uk;
Tel: +44 1412119857

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sensitivity and 95% specificity, and this indicated that a sample size of 73 patients would be appropriate. Eighty-five participants were recruited to allow for any drop-outs. A history and clinical examination was conducted by a consultant respiratory physician (SWB) and a specialist registrar (EL). Patients were recruited in a consecutive series and informed consent was obtained. The inclusion criteria were that subjects should be over 18 years of age and were judged to require a sleep study. Patients were excluded if they were involved in other research studies or did not require a sleep study. Approximately 50% of the patients were referred from their general medical practitioner, 40% from ENT surgeons, and a small number from other medical specialists as tertiary referrals. Ten percent of patients who did not have features of OSAHS were also included (to further test the validity of the Index).

The intra-oral measurements were carried out by one calibrated operator (SJ) who was blinded to the history of the patients, their presenting complaint, the provisional diagnosis and to their sleep study results. A test of the reproducibility of the measurements was carried out on six volunteers on two separate occasions before the commencement of the study. All measurements were reproducible to ± 1 mm.

The following data were obtained from each patient:

1. Height (m) and weight (kg) to allow calculation of Body Mass Index (BMI)
2. Neck circumference at cricothyroid region in centimetres (cm)
3. Palatal height (mm), measured by jenny callipers which had the sharp points modified. The advantage of these callipers is that there is an adjustable screw on one arm so the depth of the palate could be accurately measured. The callipers were sterilised before use and disposable plastic coverings were used for each patient. The measurement was taken from the midline of the dorsal surface of the tongue at the median lingual sulcus to the highest point in the palate, measured with the tongue in a relaxed position. The measurement was taken at 20 degrees of mouth opening which was established by a plastic goniometer
4. Maxillary and mandibular intermolar distance, measured from the mesial surface of the second molars with jenny callipers. If these teeth were missing, an estimate was made of the position of the mesial surface of second molars using associated anatomy and teeth present. If patients wore dentures at night, measurements were taken of the denture teeth
5. Overjet (mm).

These measurements were then used in the Kushida formula to calculate the Kushida Index.

The Kushida Index is calculated as follows:

$$\{P + (Mx - Mn) + 3 \times OJ\} + 3 \times [Max (BMI - 25,0)] \times (NC / BMI)$$

where P is the palatal height (mm) from the dorsum of the tongue at the median lingual sulcus to the highest point of the palate, measured with the tongue in a relaxed position at an opening of 20°, Mx is the maxillary intermolar distance (mm) between the mesial surfaces of the crowns of the maxillary second molars, Mn is the mandibular intermolar distance (mm) between the mesial surfaces of the crowns of the mandibular second molars, OJ is the overjet (mm), BMI is Body Mass Index, and NC is neck circumference (cm), measured at the level of the cricothyroid membrane.

The section of the formula $\{P + (Mx - Mn) + 3 \times OJ\}$ reflects the contribution of craniofacial dysmorphism, as measured from the oral cavity, to the prediction of OSAS. The section $[Max (BMI - 25,0)] \times (NC / BMI)$ reflects the contribution of obesity to the prediction of OSAS.

The fraction NC/BMI was selected to scale neck circumference relative to body size. The segment of the model enclosed within square brackets is limited to the larger of the two quantities BMI - 25, or zero. For example, if BMI is 25 or less, then [Max (BMI - 25,0)] is zero. Therefore, if a patient is not obese (that is, BMI ≤25), the contribution of the second part of the model to the final index value is nil; the final index value reflects only the degree of craniofacial dysmorphism.

Additional non-interventional measurements collected were:

1. Unit number
2. Sex
3. Age
4. Date of examination
5. Epworth score (at a later date from patient's notes)
6. Teeth present
7. Occlusal classification
8. Visual inspection of the tongue
9. Visual airway evaluation and assignment of Mallampati score (see below)
10. Visual inspection of nasal passage to assess patency.

The Mallampati score is a method used to assess the ease of intubation of a patient, graded on a scale of 1-4. This scoring method is used in anaesthetics to assess the ease with which the upper airway may be visualised during tracheal intubation.[24,25] The use of the Mallampati score was based on the results of three studies of the use of this score as a clinical predictor for OSAHS.[19–23]

Participants all had limited sleep studies (respiratory polysomnography) carried out using the Somnoscreen system (S-Med, UK) and manually analysed by a sleep technician (DM). The diagnosis of OSAHS was based on the daytime somnolence (an Epworth Sleepiness score ≥10) and an oxygen de-saturation index ≥10/hr). The criteria for the diagnosis of OSAHS were based on the recommendations in SIGN Guideline Number 73[26] and on local protocols and were as follows: an ODI (Oxygen Desaturation Index) less than 10 was considered normal; 11-15 inconclusive/borderline; 16-20 mild; 21-30 moderate; and 31 or greater was considered severe.

Statistical methods

Statistical calculations were carried out using Minitab and SPSS. Differences between means and 95% confidence intervals for each variable in OSAHS and normal patients, were calculated. P-values were calculated using an independent t test if the data were normally distributed. Where data were not normally distributed, Mann Whitney tests were used as the sample size was not sufficiently large for large sample assumptions of normality. Correlations were calculated using a Pearson's correlation coefficient for normally distributed data and a Spearman's Rank correlation coefficient for non-parametric data. When comparing categorical data, a Chi Square test was used. If the expected count was less than 5, a Fisher's exact test was used.

Sensitivity is the proportion of true positives (respiratory PSG confirmed OSAHS) that are correctly identified by the screening test (Kushida). Specificity is the proportion of true negatives (respiratory PSG confirmed not OSHAS) that are correctly identified by the screening test (Kushida).[27]

Positive predictive value is the proportion of patients with positive test results (Kushida positive) who are correctly diagnosed. Negative predictive value is the proportion of patients with negative test results (Kushida negative) who are correctly diagnosed.[28]

RESULTS

Eighty-five participants were recruited from Gartnavel General Hospital Sleep Clinic, in Glasgow, Scotland, between May and November 2007. However, of these ten failed to attend for the sleep study and four were edentulous and did not wear their dentures at night.

Of the 71 patients subsequently included in the study, 49 (69%) were fully dentate, 8 (11%) were partially dentate with enough teeth to estimate the intra-oral distances but missing one or more second molar teeth, 10 (14%) were partially dentate but had all the teeth required for calculation of the Kushida index present, and 4 (6%) were edentulous but slept with their dentures in at night.

The demographics of the patients initially recruited and those finally included in the study are summarised in Table 1. There were no statistically significant differences between these two groups in the variables listed in Table 1.

In some patients when the AHI (Apnoea-Hypopnoea Index) was not available, the ODI (Oxygen Desaturation Index) was used, as is often done in clinical practice. There was a highly significant correlation between the ODI and AHI ($r = 0.77$; $p < 0.001$, $n = 52$). Compared to patients without OSAHS, patients with OSAHS were older (50 (10.2) *vs* 43 (11.1), $p = 0.006$), had a higher BMI (35.8 (9.4) *vs* 28.9 (6.1), $p < 0.001$) and a larger collar size (43.2 ± 4.1 *vs* 39.2 ± 2.9, $p < 0.001$) (Table 2).

The cut-off used for a positive Kushida Index was 70, based on previously published data,[11] and the results may be seen in Table 3. The sensitivity of the Kushida Index in this present study was 68% (95% CI 50-81) and the specificity was 71% (95% CI 52-84). The positive predictive value was 71%; the negative predictive value was 67% (Table 3)

The diagnostic category of the patients achieved by using our criteria may be seen in Table 4. The Mallampati score, Epworth sleepiness score and enlargement of the

Table 1 Comparison of demographics of patients included and excluded from the analysis

Variable	Number measured	Mean (SD) values for those recruited	Range of values for those recruited	Number of patients included in study	Mean (SD) values for those included	Range of values for those included
Age	85	47.6 (11.2)	21-78	71	46.6 (11.2)	21-78
Gender	85	63 males		71	53 males	
Neck circumference (cm)	84	42 (4.8)	33-58.4	71	41.3 (4.1)	33-57.15
BMI	85	33.7 (8.8)	19.4-64.3	71	32.5 (8.7)	19.4-64.3
Kushida Index	84	74.2 (21.9)	31-142.6	71	71.3 (21.3)	31-142.6
Modified Mallampati score	85	3.3 (0.96)	1-4	71	3.2 (0.99)	1-4
Epworth sleepiness score	85	11.8 (5.5)	0-24	71	11.1 (5.4)	0-21

Table 2 Results for the 71 patients included in the study

	Patients with OSAHS (n = 37)	Patients without OSAHS (n = 34)	Mean difference (95% CI)	p-value *
Sex M:F	30:7	23:11		
Age (years), mean (SD)	50 (10.2)	42.85 (11.1)	-7.1 (-12.2, -2)	0.006
BMI (kg/m^2) mean (SD)	35.8 (9.4)	28.9 (6.1)	-6.8 (-10.6, -3.1)	<0.001
Neck circumference (cm) mean (SD)	43.2 (4.1)	39.2 (2.9)	-4 (-5.7, -2.3)	<0.001
Maxillary inter-molar distance (mm) mean (SD)	40.8 (3.7)	39.1 (3.5)	-1.7 (-3.4, 0.3)	0.54
Mandibular inter-molar distance (mm) mean (SD)	42.5 (4)	40.4 (4.8)	-2.1 (-4.2, -0.2)	0.048
Palatal height (cm) mean (SD)	39.2 (7.3)	41 (6.5)	1.86 (-1.4, 5.1)	0.264
Overjet median (range) {IQR}	2 (-1,8) {.5,3}	2 (0,11) {1.4,3}		0.467
ODI median (range) {IQR}	24 (11,68) {16.3,38}	3 (0,9) {1,6}		<.001
Kushida Index mean (SD)	79.2 (21.7)	62.8 (17.5)	-16.5 (-25.9, -7.1)	<0.001
Epworth sleepiness score mean (SD)	10.4 (5.5)	10.3 (5.6)	-1.4 (-3.96, 1.15)	0.27

*p-values are from independent t-tests or Mann Whitney tests

Table 3 Relationship between the diagnosis obtained from respiratory polysomnography and the results of the Kushida screening test based on a 70 cut-off

	OSAHS present	OSAHS absent	Total
Kushida positive >70	25 (71%)	10	35
Kushida negative ≤70	12	24 (67%)	36
Total	37	34	71

Table 4 The diagnostic category of the 71 patients included in the study

Diagnosis from sleep study	Number of patients
Normal	34 (48%)
Inconclusive/borderline OSAHS	8 (11%)
Mild OSAHS	9 (13%)
Moderate OSAHS	7 (10%)
Severe OSAHS	13 (18%)

tongue, soft palate or tonsils were not significantly related to a diagnosis of sleep apnoea (p >0.05).

DISCUSSION

The sensitivity and specificity of the Kushida Index for the prediction of OSAHS were found to be rather lower in this present study compared to Kushida's original results. Kushida's formula was originally based on data from 30 subjects and then prospectively tested on a further 300 subjects.[11] This formula has been further tested in Brazil by Soares *et al.* on 80 subjects and in Korea by Jung *et al.* on 54 subjects.[20,21] The inclusion of 71 subjects in this present study has been calculated to give 80%-90% adequate power at the 5% significance level. In Kushida's study, the sensitivity of the index was found to be 97.6% and the specificity was 100%, rather higher than the 68% and 71% of this present study. Jung *et al.*[20] also reported higher figures, with sensitivity of 89% and a specificity of 94%. All of these figures are based on a cut-off value of 70 in the Kushida Index.

One possible reason for the difference in the sensitivity and specificity in our study was that we used a higher threshold level for sleep apnoea (>11) than the original study by Kushida (>5). The reason for using a higher level was that an AHI of >5 is no longer considered to represent clinically significant sleep apnoea, which was not the case when Kushida published his data in 1997.[26] However, when we calculated the results using Kushida's definition of OSAHS, we obtained a sensitivity of 60% and a specificity of 76%. These values are too low to validate the Kushida Index in our population.

The gender and age distributions are similar in previous studies to this present study.[11,20,21] However, Kushida *et al.* was the only other group to publish the Epworth score; they found a larger difference (mean difference 4) between those with OSAHS and those without compared to the findings of this present study (mean difference 0.1). However, the range of Epworth scores in both studies, for those with and without OSAHS, was 5-6. Therefore it is unlikely that this is the reason for the difference in the sensitivity or specificity between this present study and Kushida's study.

There were similar neck circumferences found in all studies cited, but perhaps the largest difference between these studies was in the intra-oral measurements. In comparison to Kushida, Jung and our own results, Soares *et al.* found smaller maxillary and mandibular intermolar distances and lower palatal heights. This may be due to differences in craniofacial characteristics in that demographic area.

This present study was prospective in design, with sufficient participants to achieve a power of 80%. Although the sensitivity and specificity are considerably lower than those found by others, the authors are confident that these results are valid for the population studied. All patients were recruited in a consecutive order and the number of those diagnosed with OSAHS was similar to the number of healthy controls. The sleep technician (DM) is employed in a large sleep department and has been trained to ARTP (Association of Respiratory Technology and Physiology) standards and complies with ARTP Standards of Care for Sleep Apnoea Services.

It could be argued that all subjects without second molar teeth and anterior maxillary and mandibular incisor teeth perhaps should have been excluded from the study as it was not possible to make the intra-oral measurement in the way that Kushida intended. However, this would have distorted the applicability of the test in the West of Scotland area where a significant proportion of patients are partially dentate or edentulous. Therefore these patients were included if there was sufficient detail to reliably estimate the required intra-oral measurements. Although the reproducibility of the intra-oral measurements from the one examiner was high, it might have been desirable to have at least two examiners. However, this was not possible due to local arrangements and funding of the study.

In previous studies, if a subject had a nasal obstruction and a high Mallampati score this was correlated to a diagnosis of OSAHS.[19] However, even without nasal obstruction, those with a Mallampati score of 3 or 4 have been reported to have a 1.95 relative risk of having OSAHS.[22] The Mallampati score could be easily carried out by dentists as part of a screening procedure, but in our study a high Mallampati score was not correlated to a diagnosis of OSAHS.

Despite the lack of evidence in this study to support the usefulness of the Kushida Index and the Mallampati score, there is an authoritative protocol recommended for the screening of OSAHS in dental practice.[17] It is recommended that dentists should only treat patients who are not obese, have no relevant medical or OSAHS history and who have an ESS <10. Some dentists may wish to obtain further training in the use of home overnight recording devices, either simple pulse oximeters or more complex multi-channel devices. However, it is pointed out that although dentists may use recording devices to screen for OSAHS, they may not make a diagnosis and may not treat these patients without a prescription from an appropriate physician.

CONCLUSION

The Kushida test is quick, simple and non-invasive to perform and could easily be applied in the dental surgery. However, with the limited sensitivity and specificity demonstrated in this study, it cannot be recommended as a screening test. A primary care-based large scale study would be required before it could be recommended as a routine screening test for those with a high suspicion of OSAHS before referral to a sleep clinic.

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