

# The prediction of obstructive sleep apnea severity based on anthropometric and Mallampati indices

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**Background:** Obstructive sleep apnea (OSA) is a common health issue with serious complications. Regarding the high cost of the polysomnography (PSG), sensitive and inexpensive screening tools are necessary. The objective of this study was to evaluate the predictive value of anthropometric and Mallampati indices for OSA severity in both genders. **Materials and Methods:** In a cross-sectional study, we evaluated anthropometric data and the Mallampati classification for the patients ( $n = 205$ ) with age  $>18$  and confirmed OSA in PSG (Apnea–Hypopnea Index [AHI]  $>5$ ). For predicting the severity of OSA, we applied a decision tree (C5.0) algorithm, with input and target variables considering two models (Model 1: AHI  $\geq 15$  with Mallampati  $>2$ , age  $>51$  years, and neck circumference [NC]  $>36$  cm and Model 2: AHI  $\geq 30$  with condition: gender = female, body mass index (BMI)  $>35.8$ , and age  $>44$  years or gender = male, Mallampati  $\geq 2$ , and abdominal circumference (AC)  $>112$  then AHI  $\geq 30$ ). **Results:** About 54.1% of the patients were male. Mallampati, age, and NCs are important factors in predicting moderate OSA. The likelihood of moderate OSA severity based on Model 1 was 94.16%. In severe OSA, Mallampati, BMI, age, AC, and gender are more predictive. In Model 2, gender had a significant role. The likelihood of severe OSA based on Model 2 in female patients was 89.98% and in male patients was 90.32%. Comparison of the sensitivity and specificity of both models showed a higher sensitivity of Model 1 (93.5%) and a higher specificity of Model 2 (89.66%). **Conclusion:** For the prediction of moderate and severe OSA, anthropometric and Mallampati indices are important factors.

**Key words:** Anthropometry, body mass index, decision trees, gender, obstructive sleep apnea, polysomnography

**How to cite this article:** Amra B, Pirpiran M, Soltaninejad F, Penzel T, Fietze I, Schoebel C. The prediction of obstructive sleep apnea severity based on anthropometric and Mallampati indices. *J Res Med Sci* 2019;24:66.

## INTRODUCTION

Obstructive sleep apnea (OSA) is a common sleep disorder, and the prevalence of OSA among adult men and women is 14% and 5%, respectively.<sup>[1]</sup> The prevalence of this disorder has been reported to be 4.98% in Iranian population whereas a higher prevalence of OSA in the USA, Pakistan, and Jordan.<sup>[2]</sup> The daytime sleepiness, impaired daytime performance, lack of concentration, neurocognitive impairment and hemodynamic, and cardiovascular instability are some consequences of OSA.<sup>[3,4]</sup>

Early diagnosis as well as proper measures are essential to prevent serious complications.<sup>[5]</sup> Although

more attention has been paid to OSA in recent years, this disorder could be remained unrecognized and untreated in more than 80% of cases.<sup>[6,7]</sup> Polysomnography (PSG) is the most definitive approach to detect OSA, but it requires expert technical service and is considered as a costly procedure and not readily available. Therefore, a simpler approach with lower cost is required.<sup>[8]</sup>

To screen this disorder, various instruments have been designed such as Berlin, STOP, and STOP-Bang questionnaires.<sup>[9]</sup> Although these questionnaires were useful, the results for various races and populations are different.<sup>[10,11]</sup>

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	DOI: <a href="https://doi.org/10.4103/jrms.JRMS_653_18">10.4103/jrms.JRMS_653_18</a>

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**Received:** 30-08-2018; **Revised:** 26-10-2018; **Accepted:** 02-05-2019

On the other hand, numerous studies have reported significant effects of anthropometric indices and obesity on OSA severity.<sup>[12-14]</sup> The findings suggest that body mass index (BMI), hip circumference (HC), abdominal circumference (AC), neck circumference (NC), and modified Mallampati index as well as waist-to-hip ratio, waist-to-height ratio, and neck-to-waist ratio are associated with OSA severity.<sup>[15-24]</sup> However, no prediction analysis has performed with respect to these variables. Therefore, we evaluated the predictive value of anthropometric and Mallampati indices for OSA severity to establish an accurate predictive model.

## MATERIALS AND METHODS

### Study design and participants

The population of this cross-sectional study included patients with confirmed OSA in PSG from March 2016 to September 2017. PSG was performed in Bamdad Respiratory and Sleep Research Center in Isfahan. Cochran's sample size formula was used to determine the optimal number of sampling at 95% confidence interval, a test power of 80%, OSA prevalence of 0.49, and the Type I error rate of 0.1. Finally, a sample size of 205 was selected. The inclusion criteria were age >18 years with confirmed OSA and being consent to participate in the study. The patients with underlying disease (cardiovascular, neurologic, and severe psychological diseases) were excluded.

### Data collection

The ethical code (IR.MUI.REC.1396.3.493) was obtained from the Ethics Committee of Isfahan University of Medical Sciences, and written informed consent was collected from all patients. Overnight, PSG had been performed in all participants. Participants were connected to a set of electrodes including electroencephalography, electrooculography, electrocardiography, chin electromyogram (EMG), leg EMG, respiratory flow sensor, respiratory effort sensor, and SpO<sub>2</sub> sensor, and after the onset of sleep, a set of information was recorded and analyzed by computer. Apnea (respiratory airflow collapse) and hypopnea (respiratory airflow reduction) during sleep were recognized and measured as well. Scoring was done according to the American Association of Sleep Medicine guideline 2015.<sup>[18]</sup> Patients were classified based on the Apnea-Hypopnea Index (AHI) values without OSA (AHI < 5), mild OSA (5 ≤ AHI < 15), moderate OSA (15 ≤ AHI < 30), and severe OSA (AHI ≥ 30). Patients with AHI > 5 were diagnosed as OSA and included in the study.

Then, the HC, AC, NC, BMI, height, and age were measured.<sup>[5]</sup> Furthermore, using Mallampati classification (observations of the patient's throat), patients were classified into four classes. Class I: soft palate was completely visible; Class II:

uvula was visible; Class III: only base of uvula was visible; and Class IV: only hard palate was visible.<sup>[11]</sup>

### Statistical analysis

Finally, collected data were analyzed with SPSS (version 22, Chicago, IL, USA). The qualitative data and quantitative data were expressed as frequencies (percentage) and mean ± standard deviation and given the result of Kolmogorov–Smirnov test (normality of data distribution), and we used independent sample *t*-test and Pearson correlation coefficient. Furthermore, to evaluate and achieve a decision model for predicting the severity of OSA, we applied decision tree (C5.0) algorithm using input variables and the target variable. To establish decision tree models, input variables including gender, NC, age, BMI, AC, HC, and Mallampati index were used as the predictive variables, and two categorical variables of AHI (AHI < 15 or AHI ≥ 15; AHI < 30 or AHI ≥ 30)<sup>[16]</sup> were applied as the target variables. Severity of OSA was considered as “dependent variable.” *P* < 0.05 was considered statistically significant.

## RESULTS

The current study included 205 OSA patients (mean = 111 [54.1%]; mean age = 55.40 ± 14.16 years; mean AHI = 38.87 ± 24.23/h). Among anthropometric indices, the values of height and NC were significantly greater in men than women versus higher values of BMI, AC, and HC in women than men (*P* < 0.05) [Table 1].

Assessing the correlation between anthropometric indices and AHI showed that age, Mallampati index, and all anthropometric indices (except height) of patients were correlated with AHI (*P* < 0.05) but taking into account the gender; among female patients, there was no significant correlation between AHI and indices such as Mallampati index, height, and AC/HC ratio (*P* > 0.05).

Except AC/HC, there were significant differences between all other anthropometric and Mallampati indices and OSA severity [Table 2]. Given the presence of significant correlation of anthropometric indices, age, and gender with AHI of patients, using decision tree (C5.0), a decision model was provided to compare patients with AHI ≥ 15/h versus patients with AHI < 15/h (Model 1) and to compare patients with AHI ≥ 30/h versus patients with AHI < 30/h (Model 2). The results suggested that the likelihood of AHI ≥ 15 in patients with Mallampati > 2, age > 51 years, and NC > 36 cm was estimated to be 94.16%. In Model 2, the analysis showed that gender plays a significant role. According to this decision model, the likelihood of AHI ≥ 30/h in female patients with BMI > 35.8 kg/m<sup>2</sup> and age > 44 years was 89.98% and the likelihood of AHI ≥ 30 in male patients with Mallampati ≥ 2 and HC > 112 was estimated to be

**Table 1: Anthropometric and polysomnographic parameters of the patients**

Variables	Total (n=205)	Male (n=111)	Female (n=94)	P
Age (year)	55.40±14.16	54.69±15.92	56.24±11.80	0.444
Weight (kg)	91.25±20.04	91.80±20.39	90.58±19.70	0.670
Height (cm)	166.65±10.12	172.57±7.24	159.49±7.10	<0.001
BMI (kg/m <sup>2</sup> )	33.04±7.59	30.76±6.15	35.78±8.25	<0.001
NC (cm)	42.12±4.24	42.99±3.98	41.08±4.32	0.001
AC (cm)	114.65±18.83	112.28±17.62	117.48±19.91	0.045
HC (cm)	117.26±19.81	112.60±16.22	122.97±22.27	<0.001
AC/HC	0.98±0.10	0.99±0.07	0.96±0.12	0.015
AHI	38.87±24.23	41.80±24.39	35.41±23.71	0.060
MLPT, n (%)				
I	20 (9.8)	13 (11.7)	7 (7.4)	0.348
II	31 (15.1)	19 (17.1)	12 (12.8)	
III	87 (42.4)	48 (43.2)	39 (41.5)	
IV	67 (32.7)	31 (27.9)	36 (38.3)	

Data were shown as mean±SD or n (%). NC=Neck circumference; AC=Abdominal circumference; HC=Hip circumference; AHI=Apnea-Hypopnea Index; MLPT=Mallampati index; SD=Standard deviation

**Table 2: Anthropometric and Mallampati indices with respect to Apnea-Hypopnea Index**

Variables	AHI			P
	Mild	Moderate	Severe	
Age	47.75±12.10	54.64±15.63	57.13±13.13	0.037
Weight	82.55±18.51	86.91±17.42	95.19±20.80	0.003
Height	166.80±10.78	165.50±10.39	167.63±9.76	0.393
BMI	29.75±6.57	31.97±7.37	34.05±7.55	0.028
NC	40.80±3.53	41.42±4.18	42.79±4.35	0.022
AC	103.65±21.13	112.44±17.55	117.65±18.23	0.004
HC	108.30±21.75	115.77±17.91	119.54±20.06	0.051
AC/HC	0.96±0.11	0.97±0.07	0.99±0.11	0.353
MLPT	2.20±0.83	3.03±0.90	3.06±0.92	<0.001

Data were shown mean±SD. NC=Neck circumference; AC=Abdominal circumference; HC=Hip circumference; AHI=Apnea-Hypopnea Index; MLPT=Mallampati index; BMI=Body mass index; OSA=Obstructive sleep apnea; AHI group=Mild OSA (5≤AHI <15 events/h); moderate OSA (15≤AHI ≤30 events/h); and severe OSA (AHI >30 events/h)

90.32% [Table 3]. Finally, the assessment of sensitivity and specificity of both models showed a higher sensitivity of Model 1 (93.5%) than Model 2 but a higher specificity of Model 2 (89.66%) than Model 1. Thereby, to predict the severity of OSA, Model 1 benefits from a higher sensitivity to diagnose patients with AHI ≥15, whereas Model 2 is more specific to predict AHI ≥30 in OSA patients [Table 4].

## DISCUSSION

This study represented a predictive model for the OSA severity in the Iranian adult population. Hence, accessible and easy-to-obtain indices (including anthropometric indices, age, and gender of patients) were used, and to achieve a proper model, decision tree (C.5) was applied. At the first step, a significant positive correlation was found between anthropometric indices (NC, AC, and age) and Mallampati index with AHI. Afterward, these parameters

**Table 3: The results of decision tree (C=5.0)**

The rules to predict the severity of OSA	Probability (%)	
AHI ≥15 versus AHI <15	If Mallampati >2, age >51 years, and NC >36 cm, then AHI ≥15	94.16
AHI ≥30 versus AHI <30	If gender: female, BMI >35.8, and age >44 years then AHI ≥30	89.98
	If gender: male, Mallampati ≥2, and AC >112 then AHI ≥30	90.32

NC=Neck circumference; AC=Abdominal circumference; BMI=Body mass index; AHI=Apnea-Hypopnea Index

**Table 4: The comparison of diagnostic values of two models obtained from decision tree (C=5.0)**

Result model of C5	AUC±SE	95% CI		+PV	-PV
		Sensitivity	Specificity		
Model 1	0.718±0.06	93.51 (88.9–96.6)	50 (27.2–72.8)	94.5	45.5
Model 2	0.732±0.03	56.78 (47.3–65.9)	89.66 (81.3–95.2)	88.2	60.5

Model 1=AHI ≥15 with condition: Mallampati >2, age >51 years, and NC >36 cm; Model 2=AHI ≥30 with condition: Gender: female, BMI >35.8 and age >44 years or gender: male, Mallampati ≥2, and AC >112 then AHI ≥30. BMI=Body mass index; AHI=Apnea-Hypopnea Index; NC=Neck circumference; AC=Abdominal circumference; SE=Standard error; CI=Confidence interval; AUC=Area under the ROC curve; ROC=Receiver operating characteristic; PV=Predictive value

were inserted into the decision model for predictors of OSA severity. Therefore, two decision models were represented using these variables.

Model 1 represented a decision model for the identification and anticipation of patients with AHI ≥15. The results indicated that the likelihood of AHI ≥15 in patients with Mallampati >2, age >51 years, and NC >36 cm was approximately 94.16%. The sensitivity of the model was very high and its positive predictive value was acceptable. Thus, the model can be identified as a predictive model to distinguish patients based on AHI <15 versus AHI ≥15.

Model 2 represented a decision model for the identification and anticipation of patients with AHI ≥30. In Model 2, gender was an important factor, and the predictive model was different for both genders. The likelihood of AHI ≥30 in female patients with BMI >35.8 kg/m<sup>2</sup> and age >44 years was approximately 89.98%, and the likelihood of AHI ≥30 in male patients with Mallampati ≥2 and HC >112 cm was approximately 90.32%. The sensitivity and specificity of the model in predicting AHI <30 versus AHI ≥30 were 56.78% and 89.66%, respectively. Although the sensitivity of this model is lower than Model 1, its negative predictive value is higher.

In line with this study, Kang *et al.* in South Korean population suggested obesity as a major risk factor for OSA and a significant positive correlation between all anthropometric indices and the OSA severity.<sup>[20]</sup> In addition, many studies have shown a significant correlation

between indices including age, height, weight, BMI, neck/waist circumference (WC), HC and AC/HC ratio, and AHI. This correlation was significant among OSA patients compared to controls.<sup>[5,21,22]</sup> Moreover, the division based on gender by investigators showed a higher prevalence of OSA in men than women. Furthermore, there is a stronger correlation between AC/HC ratio and the severity of OSA in men than women whereas the presence of stronger correlation between BMI and the severity of OSA in women than men.<sup>[5,23,25]</sup>

Liu *et al.* classified OSA patients based on AHI scores of 15 and 30 and attempted to predict the OSA severity based on support vector machine as the model which is called "body profile model." They found that three parameters of WC, BMI, and NC as well as age can predict OSA severity. They suggested that it could be accurate to distinguish between patients with AHI  $\geq 30$  and AHI  $< 30$  among young females in Asia, but the result was slightly worse for males. Their model could be a reasonable instrument to screen patients and rule out moderate-to-severe OSA.<sup>[1]</sup>

Few studies have pointed out the importance of Mallampati index to diagnose and predict OSA severity. For example, Davidson and Patel have shown that Mallampati index could be effective in evaluating fat deposition in the tongue and measuring obesity. They found the correlation between Mallampati index and AHI in male patients.<sup>[25]</sup>

Nashi *et al.* found the relationship between increased tongue volume and a higher Mallampati index. Therefore, it was associated with a high outbreak and severity of sleep disorders.<sup>[26]</sup> Pinto *et al.* also applied the Mallampati index as an anthropometric measurement and found that it is significantly associated with PSG parameters such as the AHI.<sup>[21]</sup>

In line with this study, previous literature has reported that male OSA patients even with similar BMI and WC had greater upper body (chest and abdomen) obesity.<sup>[27]</sup> It means that fat distribution can play an important role in OSA development. Furthermore, more neck fat in male than female OSA patients has been reported.<sup>[28]</sup>

Another study had applied logistic regression to identify effective anthropometric indices in OSA severity. The study showed that after adjusting for age and gender, indices including NC, WC, and BMI were effective in OSA, and using receiver operating characteristic analysis, the authors suggested different cutoff values to predict OSA in females and males. The cutoff values for females were NC of 34.5 cm, HC of 76.5 cm, and BMI of 23.05 kg/m<sup>2</sup>, whereas the cutoff values for males were NC of 38.75 cm, HC of 88.5 cm, and BMI of 24.95 kg/m<sup>2</sup>.<sup>[17]</sup>

To predict the presence of OSA, Cizza *et al.* have reported that an NC  $\geq 38$  cm had a sensitivity of 58% and a specificity of 79%.<sup>[29]</sup> Soylu *et al.* have noted a greater value of NC than WC with respect to an association with OSA in Turkish adults.<sup>[30]</sup> Furthermore, they stated that to predict OSA, the optimal cutoff values of NC were 35.5 cm in females and 39 cm in males. Zhou *et al.* have mentioned NC values of 33 cm for females and 37 cm for males as the optimal cutoff values for metabolic syndrome in Chinese adults with OSA.<sup>[31]</sup>

Martins *et al.* in Brazil have suggested a similar trend in the literature.<sup>[32]</sup> The study determined a cutoff value of NC = 40 cm for OSA risk in males compared to the related cutoff value of 36 cm in females. Furthermore, Davidson *et al.* in the USA have reported that the presence of OSA could be determined by related values of 43 cm for males and 38 cm for females.<sup>[33]</sup>

Overall, the results of the current study and other studies indicated that anthropometric indices, as well as age and gender, could be effective in predicting the presence and the severity of OSA. While a small sample size of this study could be mentioned as one of the limitations, larger sample size can increase the accuracy of provided model to identify the target variables as well as the possibility of generalization. Thus, it seemingly requires more studies with larger sample sizes and in various populations of different countries because it is likely that the anthropometric conditions of people in different societies follow a variety of patterns, and we need further studies in this field to achieve a unified predictive model.

## CONCLUSION

According to the results, anthropometric indices are positively correlated with AHI. Based on decision model (C 5.0), the likelihood of AHI  $\geq 15$  in patients with Mallampati score  $> 2$ , age  $> 51$  years, and NC  $> 36$  cm was estimated to be 94.16% (Model 1) and the likelihood of AHI  $\geq 30$  in female patients with BMI  $> 35.8$  kg/m<sup>2</sup> and age  $> 44$  years was estimated to be 89.98%, whereas the likelihood of AHI  $\geq 30$  in male patients with Mallampati score  $\geq 2$  and AC  $> 112$  cm was estimated to be 90.32% (Model 2). In general, Model 1 showed a higher accuracy, sensitivity, and predictive value than Model 2.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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