Neck Circumference – Height Ratio Cut-Off as a Predictor of Obstructive Sleep Apnea Severity among Adult Patients Diagnosed with Obstructive Sleep Apnea at the Lung Center of the Philippines

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Abstract

INTRODUCTION: Obstructive sleep apnea (OSA) is the most common breathing-related sleep disorder. OSA is mainly characterized by a set of symptoms resulting from apnea events that have negative outcomes on health, such as excessive daytime sleepiness, cardiovascular impairment, and increased morbidity and mortality. It is important to develop simple, reliable, cost-effective methods to predict obstructive sleep apnea. Neck circumference - height ratio has limited studies in its relation to obstructive sleep apnea compared to neck circumference.

METHOD: This is a retrospective cross-sectional study using chart review of all patients who had been diagnosed with obstructive sleep apnea by polysomnogram at the Lung Center of the Philippines from January 2019 to December 2019. Demographic characteristics like age, gender, weight, height, neck circumference, BMI, neck circumference – height ratio [NHR], and apnea-hypopnea index were determined. Accuracy of the neck circumference – height ratio cut-off had been determined in predicting obstructive sleep apnea and its severity by comparing neck – circumference – height ratio cut-off with a polysomnogram.

RESULTS: Among the 384 charts collected and reviewed, this study had a total of 194 participants were included. Most participants were male (72.68%) and the age range was between 35 to 60 years old. There were 12 (6%) participants in the Mild OSA group, 19 (10%) in the Moderate OSA group, and 163 (84%) were categorized as Severe. Median Neck Circumference – Height Ratio was 0.23 to 0.26. A cutoff of > 0.23 NHR was used to predict Mild OSA showed PPV of 46.15% (24.47 to 65.98), NPV was 66.67% (50.78 to 79.49), AUC of 0.5307 (0.30 to 0.76), and accuracy of 58.06% (39.08 to 75.45). A cutoff of > 0.23 NHR was used to predict Moderate OSA showed positive predictive value (PPV) was 15.94% (10.91 to 22.7), NPV of 93.6% (89.52 to 96.16), AUC of 0.6421 (0.52 to 0.77), and accuracy of 65.98% (58.85 to 72.61). A cutoff of > 0.23 NHR was used to predict Severe OSA showed PPV of 15.94% (10.91 to 22.7), NPV of 93.6% (89.52 to 96.16), AUC of 0.6421 (0.52 to 0.77), and accuracy of 65.98% (58.85 to 72.61).

CONCLUSION: The NHR cut-off demonstrated a moderate positive correlation with OSA, and NHR increases as the apnea-hypopnea index are increased. NHR cut-off of 0.23 is sufficient to predict severe OSA but has poor diagnostic accuracy for mild and moderate OSA. Moreover, the NHR cut-off may also be an integral tool to predict severe OSA.

Keywords: *Neck Circumference-height ratio, obstructive sleep apnea*

INTRODUCTION

BACKGROUND

Obstructive sleep apnea (OSA) is the most common breathing-related sleep disorder.The disease causes changes in respiratory patterns leading to intermittent hypoxia, hypercapnia, and increased frequency of awakenings. OSA is mainly characterized by a set of symptoms resulting from apnea events that

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have negative outcomes on health, such as excessive daytime sleepiness, cardiovascular impairment, and increased morbidity and mortality. Obesity, gender, genetic, and hormonal factors mediate risk for OSA and interact in a multifaceted manner in the pathogenesis of this disease. Obesity is the most established and primary risk factor for OSA [1]. There is a linear correlation between obesity and OSA [2]. Not only in adults, but also the pediatric obesity has caused serious concern all over the world as the prevalence has increased alarmingly over time in developed and developing countries [3]. The prevalence of OSA in the general population is 3 to 7 % for men and 2 to 5 % for women [2]. Mallampati score, age, and neck circumference (NC) are important factors in predicting moderate OSA. Meanwhile, Mallampati score, body mass index (BMI), age, abdominal circumference (AC), and gender are more predictive for severe OSA [4]. In obese people, fat deposits in the upper respiratory tract narrow the airway; there is a decrease in muscle activity in this region, leading to hypoxic and apneic episodes, ultimately resulting in sleep apnea. Those with the greatest weight gain had a more severe apnea-hypopnea index (AHI) [Error! Bookmark not defined.]. In addition, OSA and Obesity share common mechanisms such as inflammatory activation, oxidative stress, and increased sympathetic activity [5].

It is important to develop simple, reliable, cost-effective methods to predict obstructive sleep apnea. One option is to use anthropometric variables relating to obesity. Anthropometric measures are essential tools used for health evaluation, especially in relation to obesity. The BMI, waist-to-height ratio, neck and waist circumference arethe most widely used. Neck circumference (NC) is a variable tool often considered in sleep medicine due to its capability to predict sleep events [1].

Another way to approach the distribution of fat in the human body is to analyze its relative distribution. If one imagines the neck as more or less a cylinder, then the “thickness” or circumference of the neck will be mathematically proportional to its length for any given neck mass. Further, since neck length is difficult to accurately and reproducibly measure, under an assumption of proportionality of the normal human body, neck length should be proportional to overall height, even under circumstances of obesity. Neck circumference -height ratio (NHR) can be a useful additional aid to predict obstructive sleep apnea [6].

Neck circumference - height ratio has limited studies in its relation to obstructive sleep apnea compared to neck circumference. However, developing evidence suggests that the neck-to-height ratio (NHR) is an innovative index for the evaluation of upper body adipose distribution in patients with a sleep-related breathing disorder [6**Error! Bookmark not defined.**].

Locally, no studies have been published yet looking into the correlation between the NHR cut-off and OSA severity and the predictive value of NHR cut-off in determining the OSA severity. This study aims to contribute to the limited existing body of knowledge in setting cut-off points for the neck circumference – height ratio in the presumptive diagnosis of obstructive sleep apnea and its severity. Once the cut-off values have been determined to be of significant diagnostic accuracy and good predictive value, future studies are recommended on comparing our cut-offs derived from this study with other anthropometric measurements like neck circumference and waist-to-hip ratio in determining obstructive sleep apnea severity.

GENERAL OBJECTIVES

To determine the predictive value of the neck circumference-height ratio cut-off in determining the obstructive sleep apnea severity among adult patients diagnosed with obstructive sleep apnea at the Lung Center of the Philippines from January 2019 to December 2019

SPECIFIC OBJECTIVES

1. To determine demographic profile., anthropometric measurements and neck circumference – height ratio (NHR) cut-off among the different severity of obstructive sleep apnea (Mild OSA, Moderate OSA, and Severe OSA) according to:
    a. Age
    b. Gender
    c. Weight

d. Height
e. Body mass index
f. Neck circumference
g. Apnea – hypopnea index

2. To determine the correlation of neck circumference – height ratio (NHR) cut-off among the different severities of obstructive sleep apnea (Mild OSA, Moderate OSA, and Severe OSA)

3. To evaluate the diagnostic accuracy of the neck circumference – height ratio (NHR) cut-off in predicting the different severities of obstructive sleep apnea (Mild OSA, Moderate OSA, and Severe OSA)
    a. Sensitivity
    b. Specificity
    c. Negative predictive value
    d. Positive predictive value
    e. Negative Likelihood ratio
    f. Positive Likelihood ratio
    g. Area under the Receiver operating characteristics curve

METHODOLOGY

This was a retrospective cross-sectional study conducted at the Lung Center of the Philippines, a tertiary, specialty medical center. This study involved a chart review of all patients who had been diagnosed with obstructive sleep apnea by polysomnogram at the Lung Center of the Philippines from January 2019 to December 2019.

Patients included in the study have the following inclusion criteria: age 18 years old and above, diagnosed with obstructive sleep apnea (AHI of equal or more than 5 events/hour) via type 1 or in-hospital polysomnogram at Lung Center of the Philippines, and full night diagnostic or split night polysomnogram had been performed on the patient.

Patients excluded in the study have the following exclusion criteria: patients with genetic syndromes (Down syndrome, Prader-Willi syndrome), patients with tracheostomy, patients with enlarged thyroid gland (hyper or hypothyroidism), patients with incomplete data in the chart, patients with normal polysomnogram results (AHI of less than 5 events/hour), and full night therapeutic polysomnogram had been performed on the patient.

ETHICAL CONSIDERATION

We conducted this study in compliance with the ethical principle set in the Declaration of Helsinki and RA10173 or Data Privacy Act of 2012. A review of the clinical protocol was completed by the Research Review Committee of the Department of Pulmonary Medicine, and Institutional Ethics Review Board, Lung Center of the Philippines. Informed consent was waived due to the retrospective nature of the study.

Anthropometric indices measurement:

As per protocol of the sleep laboratory in the Lung Center of the Philippines; age and gender are routinely taken. Height (cm) is measured with the use of the stadiometer component of the DETECTO measuring scale by letting the participant stand upright on the stadiometer without shoes, facing forwards as tall andstraight as possible with their arms hanging loosely at their sides, their feet should be flat on the base plate of the stadiometer and positioned slightly apart, and knees should be straight. The sleep personnel standing at the side should then bring the head plate of the stadiometer down onto the head, ensuring it rests on the crown of the head ,and read the level with counter/pointer and measurement read to the nearest 1mm. Weight (kg) is taken using the balance beam scale component of the DETECTO measuring scale, with street clothes without extra outerwear by letting the patient stand straight upright at the base plate of the measuring scale, face facing forward, and remain still as possible. The sleep personnel will adjust the sliding weights to determine the weight of the patient. Both the height and the weight were taken by using the DETECTO measuring scale located near the sleep laboratory (Ward 3A of the Lung Center of the Philippines). Neck circumference (cm) was measured by placing the measuring tape at the point just above the cricoid cartilage to the nearest 0.5 cm, while the patient is

sitting upright on a chair facing forward. BMI was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). All measurements were taken at the sleep laboratory by the sleep technologists or sleep fellows in training. The neck circumference-height ratio will be calculated as neck circumference in centimeters divided by height in centimeters.

Obstructive sleep apnea diagnosis and severity classification in adults:

The diagnosis of sleep apnea should be confirmed objectively by sleep testing. The "gold standard" test is Polysomnogram. Scoring of the sleep study was performed according to the American Academy of Sleep Medicine (AASM) 2018 (version 2.5) guidelines, which was current for that time period. The AHI and other variables were derived from polysomnography (PSG) report and archived for later potential retrieval within the sleep laboratory at the Lung Center of the Philippines database. The diagnosis of OSA is confirmed if the number of obstructive events on PSG is greater than 15 events/hour with the absence of sleep-related symptoms (sleepiness, non-restorative sleep, fatigue, or insomnia, wakes up with breath-holding, gasping, or choking, habitual loud snoring, breathing interruptions, or both during the patient's sleep) or greater than 5 events/hour with sleep-related symptoms. OSA severity is classified as **mild** for AHI 5-14/hour, **moderate** for AHI 15-30/hour, and **severe** for AHI > 30/hour.

Data Collection

Data had been collected by chart review from all the patients at the Lung Center of the Philippines with obstructive sleep apnea by type 1 polysomnogram from January to December 2019. After the collection of the charts, they were segregated whether they can be included or not. Demographic characteristics like age, gender, weight, height, neck circumference, BMI, neck circumference – height ratio, and apnea-hypopnea index were determined. Accuracy of the neck circumference – height ratio cut-off had been determined in predicting obstructive sleep apnea and its severity by comparing neck – circumference – height ratio cut-off with a polysomnogram.

STATISTICAL ANALYSIS

Descriptive statistics wereused to summarize the demographic and clinical characteristics of the patients. Frequency and proportion were used for categorical variables and median and interquartile range for non-normally distributed continuous variables. Kruskal-Wallis test and Fisher's exact test wereused to determine the difference of rank and frequency, respectively, within different Obstructive Sleep Apnea severity. The area under the receiver operating characteristics curve, as well as its diagnostic parameters, wereused to determine the diagnostic accuracy of the Neck Circumference – Height ratio in predicting different levels of Obstructive Sleep Apnea severity. Pearson product-moment correlation was used to determine the linear correlation between Neck Circumference – Height ratio and Apnea-Hypopnea Index. Shapiro-Wilk was used to test the normality of the continuous variables. Null hypotheses were rejected at 0.05α-level of significance. STATA 13.1 was used for data analysis.

RESULTS AND DISCUSSION

DEMOGRAPHICS

Table 1. Demographic profile, anthropometric measurements, and neck circumference - height ratio (NHR) of obstructive sleep apnea patients (n=194)

	Frequency (%); Median (IQR)
Age	46 (35 to 60)
Gender	
Male	141 (72.68)
Female	53 (27.32)
Weight	83.55 (71.5 to 97.5)
Height	165 (156.5 to 170)
BMI	30.84 (26.81 to 36)
Neck Circumference	40 (37 to 43)
Neck Circumference – Height ratio	0.25 (0.23 to 0.26)
Apnea-Hypopnea Index	75.2 (43.9 to 98.6)

Among the 384 charts collected and reviewed, this study had a total of 194 participants who met the inclusion criteria. One hundred ninety charts were excluded due to incomplete data, normal results, and a full therapeutic sleep study was performed on the patient. The demographic profile of the participants included Age, Gender, Weight, Height, BMI, Neck Circumference, Neck Circumference-Height Ratio, and the Apnea-Hypopnea Index (Table 1). Most participants were male (72.68%) and females comprised the remainder (27.32%) of the study population. Frequency (%) and median (IQR) values were calculated for each domain. The age range was between 35 to 60 years old. The median weight was 71.5 to 97.5 kg. The median height was 156.5 to 170 cm. Median BMI was categorized as Overweight up to Obese Class II (26.81 to 36 kg/m^2). Median Neck Circumference was 37 to 43 cm. Median Neck Circumference – Height Ratio was 0.23 to 0.26. Median Apnea-Hypopnea Index was 43.9 to 98.6.

Table 2. Demographic profile, anthropometric measurements, and neck circumference – height ratio (NHR) among the different severity of obstructive sleep apnea

	Obstructive Sleep Apnea			P-value
	Mild (n=12, 6%)	Moderate (n=19, 10%)	Severe (n=163, 84%)	
	Frequency (%); Median (IQR)			
Age	34 (24.5 to 46.5)	56 (45 to 69)	45 (36 to 69)	0.009
Gender				0.020
Male	5 (41.67)	12 (63.16)	124 (76.07)	
Female	7 (58.33)	7 (36.84)	39 (23.93)	
Weight	66.2 (59 to 75.4)	69.6 (64.5 to 81)	87.4 (75 to 101.3)	<0.001
Height	156 (152 to 165)	164 (156 to 168)	165 (160 to 170)	0.060
BMI	26.3 (23.7 to 30)	26.5 (23.7 to 33.1)	31.4 (27.8 to 37)	<0.001
Neck Circumference	36.5 (34 to 39.8)	37 (36 to 39)	41 (37 to 43.7)	<0.001
Neck Circumference – Height ratio	0.23 (0.2 to 0.26)	0.23 (0.22 to 0.25)	0.25 (0.23 to 0.26)	0.021
Apnea-Hypopnea Index	9.3 (7.55 to 10.4)	20.7 (18.3 to 28)	81.7 (63.2 to 104)	<0.001

The severity of OSA according to three categories (Mild, Moderate, Severe) were correlated with the demographic profile (Table 2). There were 12 (6%) participants in the Mild OSA group, 19 (10%) in the Moderate OSA group, and 163 (84%) were categorized as Severe. Frequency (%) and Median (IQR) were calculated per domain.

In the Mild OSA group, the median age range was 24.5 to 46.5 years old. Most were female (58.33%) and the rest were male (41.67%). Median weight was 59 to 75.4 kg and median height was 152 to 165 cm. Median BMI was 23.7 to 30 kg/m^2. Median Neck Circumference was 34 to 39.8 cm, and the median Neck Circumference-Height Ratio was 0.2 to 0.26. The median Apnea-Hypopnea Index was 7.55 to 10.4.

In the moderate OSA group, the median age range was 45 to 69 years old. Most were male (63.16%) and the rest were female (36.84%). Median weight was 64.5 to 81 kg and median height was 156 to 168 cm. Median BMI was 23.7 to 33.1 kg/m^2. Median Neck Circumference was 36 to 39 cm, and the median Neck Circumference-Height Ratio was 0.22 to 0.25. The median Apnea-Hypopnea Index was 18.3 to 28.

In the severe OSA group, the median age range was 36 to 69 years old. Most were male (76.07%) and the rest were female (23.93%). Median weight was 75 to 101.3 kg and median height was 160 to 170 cm. Median BMI was 27.8 to 37 kg/m^2. Median Neck Circumference was 37 to 43.7 cm, and the median Neck Circumference-Height Ratio was 0.23 to 0.26. The median Apnea-Hypopnea Index was 63.2 to 104.

A p-value less than 0.05 denoted statistical significance. OSA category (Mild, Moderate, Severe) was statistically significant for the following variables: age (p=0.009); gender (p=0.020); Neck Circumference-Height Ratio (p=0.021); weight, BMI, Neck Circumference, and the Apnea-Hypopnea Index were all p<0.001. Most of the associations were statistically significant except for height (p=0.060).

Anthropometric indices of obesity (e.g., BMI, waist circumference, and neck circumference) are associated with poor long-term cardiovascular outcomes [2-4]. Previous research has found a link between neck circumference and central body adiposity [2-5]. Thus, an association between upper body fat and cardiovascular risk heightens interest in neck fat. The neck is a well-defined cylindrical compartment that may be assessed and measured by relatively simple means. Due to its ability to predict sleep apnea events, neck circumference is a variable frequently considered in sleep medicine [7]. Fat accumulation in the cervical region has been shown to significantly reduce upper airway diameter. In addition, the neck circumference demonstrated a moderate correlation with cardiovascular risk factors compared with BMI and visceral adipose tissue [1]. Additionally, the large neck circumference is associated with insulin resistance and dyslipidemia, thus clarifying the connection between this metric and cardiovascular outcome [8]. In a clinical study performed by Polesel et al. (2019) involving 1,042 participants who underwent complete full-night PSG, screening methods such as anthropometric measures and effectiveness were utilized to diagnose OSA in both treatment groups [1]. Determining the waist circumference and waist-to-hip ratio (WHR) in the women's treatment arm was an ideal assessment to measure sleep-disordered breathing (SDB). Nonetheless, waist-to-height ratio and neck circumference were the best measures in the men with mild OSA; however, BMI was found to be more closely associated with severe OSA. An increase in neck circumference and the waist-to-height ratio of one unit may increase the probability of OSA by 15% and 13%, respectively [1]. According to asleep cohort study conducted by Young et al. (2009) involving 6,050 patients with sleep issues, incidence rates on having SDB with an AHI >5 was lower at 9% for women compared to 24% for the men. Meanwhile, AHI>15 was reported in 4% of women and 9% for men [9].

OSA prevalence was found to increase progressively with age in a probability sample from two Pennsylvania counties. OSA (AHI>10 events/hour) was reported in 3.2% of men aged 20 to 44 years, 11.3% of men aged 45 to 64 years, and 18.1% of men aged 61 to 100 years. Concurrently, the prevalence of OSA (AHI > 15 events/hour) in women was 0.6%, 2.0%, and 7.0%, respectively, for the 20 to 44year, 45 to 64years, and 61-to-100-year age groups [10,11,12].Similar results have been demonstrated in a community-based Sleep Heart Health Study, wherein the disease prevalence increases steadily with age and reaches a plateau after the age of 60 [10,13]. Furthermore, an epidemiologic study investigated the prevalence of OSA in adults; it was reported that men have higher rates of OSA with a lower male-to-female ratio in the range 2 to 3:1 [10]. The male predisposition to the disorder has been attributed to gender differences in upper airway anatomical and functional properties, as well as the ventilatory response to sleep arousals [10].

The modest to strong correlation between these inter-related measures poses a challenge in determining whether such factors of central obesity can better predict disease risks or severity (i.e., BMI, waist girth, neck circumference). Nonetheless, cross-sectional analyses of the Sleep Heart Health Study data revealed that moderate to severe OSA, as defined as an AHI > 15 events/hour, is independently associated with BMI, neck circumference, and waist circumference in middle-aged and elderly [10,13].

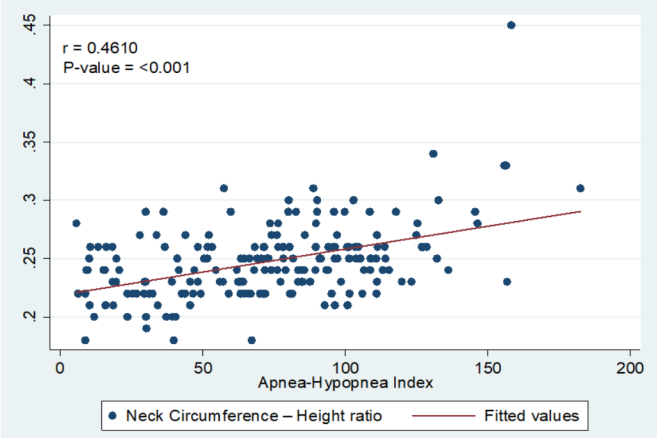
Numerous evidences have consistently identified bodyweight as the strongest risk factor to exhibit OSA. This was assessed and confirmed by the

Wisconsin Sleep Cohort study, which found that a one standard deviation difference in BMI was associated with a fourfold increase in disease prevalence [10]. Given that the pathophysiology of OSA is completely linked with obesity, with an estimated 58% of moderate to severe cases being attributable to a BMI ≥ 25 kg/m^2 [10,15].

Another factor associated with OSA was neck circumference. This was investigated in a retrospective, case-control observational study conducted by Si Eun Kim et al. (2015) with 147 snoring patients. The authors concluded that neck circumference assessment may predict the presence and severity of OSA [16]. Results revealed that a significant correlation between AHI and neck circumference was observed (P<0.0001). Moreover, there was more association between the neck circumference and OSA rather than BMI and age [16]. The results were further evaluated by an observational, cross-sectional pilot study by Ang et al. (2011) [17].Neck circumference cut-off levels of 40cm for males and 33.8cm for females demonstrated low sensitivity and moderately high specificity for identifying patients with abdominal obesity (n=425); 62.07% and 90.09% for males, 67.59% and 85.6% for females, respectively [17]. Except for hypertriglyceridemia, patients with obese neck circumference cut-off levels had asignificant association with component risk factors of metabolic syndrome (MetS) (P<0.001). Hence, potential risk of cardiovascular disease [17].

NHR CUT-OFF

Figure 1: NHR cut-off versus AHI



***Pearson's r interpretation: ≥ 0.7 (strong relationship), 0.4-0.69 (moderate relationship), 0.1- 0.39 (weak relationship), 0 (no or negligible relationship). Adapted from: Dancey C, Reidy J. 2004. Statistics without maths for psychology: using SPSS for windows. London, England: Prentice-Hall**

Table 3.1 Diagnostic accuracy of Neck Circumference – Height ratio to predict Mild OSA

		Obstructive Sleep Apnea		Total
		Mild	Moderate	
NHR	≤ 0.23	6	7	13
	> 0.23	6	12	18
	Total	12	19	31

Sensitivity	50% (21.09 to 78.91)	Positive LR	1.36 (0.60 to 3.07)
Specificity	63.16% (38.36 to 83.71)	Negative LR	0.79 (0.41 to 1.53)
PPV	46.15% (24.47 to 65.98)	AUC	0.5307 (0.30 to 0.76)
NPV	66.67% (50.78 to 79.49)	Accuracy	58.06% (39.08 to 75.45)

PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio.

The diagnostic accuracy of Neck Circumference-Height Ratio using Moderate OSA as its reference outcome to predict Mild OSA is shown in Table 3.1. A cutoff of ≥ 0.23 NHR was used to predict Mild OSA using Moderate as the reference (sensitivity: 50% (21.09 to 78.91); specificity: 63.16% (38.36 to 83.71). The PPV was 46.15% (24.47 to 65.98) and the NPV was 66.67% (50.78 to 79.49). The positive likelihood ratio was 1.36 (0.60 to 3.07) and the negative likelihood ratio was 0.79 (0.41 to 1.53). The AUC was determined as 0.5307 (0.30 to 0.76) and the accuracy yielded from the cutoff was 58.06% (39.08 to 75.45).

Table 3.2 Diagnostic accuracy of Neck Circumference – Height ratio to predict Mild OSA

		Obstructive Sleep Apnea		Total
		Mild	Moderate and Severe	
NHR	≤ 0.22	6	40	46
	> 0.22	6	142	148
	Total	12	182	194

Sensitivity	50% (21.09 to 78.91)	Positive LR	2.27 (1.21 to 4.27)
Specificity	78.02% (71.30 to 83.81)	Negative LR	0.64 (0.36 to 1.13)
PPV	13.04% (7.41% to 21.95)	AUC	0.6465 (0.47 to 0.82)
NPV	95.95% (93.04 to 97.67)	Accuracy	76.29% (69.67 to 82.09)

PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio.

The diagnostic accuracy of Neck Circumference-Height Ratio using Moderate and Severe OSA as reference outcomes to predict Mild OSA is shown in Table 3.2. A cutoff of ≥ 0.22 NHR was used to predict Mild OSA using Moderate and Severe as reference outcomes (sensitivity: 50% (21.09 to 78.91); specificity: 78.02% (71.30 to 83.81). The PPV was 13.04% (7.41% to 21.95) and the NPV was 95.95% (93.04 to 97.67). The positive likelihood ratio was 2.27 (1.21 to 4.27) and the negative likelihood ratio was 0.64 (0.36 to 1.13). The AUC was determined as 0.6465 (0.47 to 0.82) and the accuracy yielded from the cutoff was 76.29% (69.67 to 82.09).

Table 4.1 Diagnostic accuracy of Neck Circumference – Height ratio to predict Moderate OSA

		Obstructive Sleep Apnea		Total
		Moderate	Mild	
NHR	≥ 0.23	12	6	18
	< 0.23	7	6	13
	Total	19	12	31

Sensitivity	63.16% (38.36 to 83.71)	Positive LR	1.26 (0.65 to 2.45)
Specificity	50% (21.09 to 78.91)	Negative LR	0.74 (0.33 to 1.67)
PPV	66.67% (50.78 to 79.49)	AUC	0.5307 (0.30 to 0.76)
NPV	46.15% (27.47 to 65.98)	Accuracy	58.06% (39.08 to 75.45)

PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio.

The diagnostic accuracy of Neck Circumference-Height Ratio using Mild OSA as its reference outcome to predict Moderate OSA is shown in Table 4.1. A cutoff of ≥ 0.23 NHR was used to predict Moderate OSA using Mild as its reference (sensitivity: 63.16% (38.36 to 83.71); specificity: 50% (21.09 to 78.91). The positive predictive value (PPV) was 66.67% (50.78 to 79.49) and the negative predictive value (NPV) was 46.15%27.47 to 65.98). The AUC was determined as 0.5307 (0.30 to 0.76) and the accuracy yielded from the cutoff was 58.06% (39.08 to 75.45).

Table 4.2 Diagnostic accuracy of Neck Circumference – Height ratio to predict Moderate OSA

		Obstructive Sleep Apnea		Total
		Moderate	Mild and Severe	
NHR	≤ 0.23	11	58	69
	> 0.23	8	117	125
	Total	19	175	194

Sensitivity	57.89% (33.5 to 79.75)	Positive LR	1.75 (1.13 to 2.71)
Specificity	66.86% (59.36 to 73.78)	Negative LR	0.63 (0.37 to 1.08)
PPV	15.94% (10.91 to 22.7)	AUC	0.6421 (0.52 to 0.77)
NPV	93.6% (89.52 to 96.16)	Accuracy	65.98% (58.85 to 72.61)

PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio.

The diagnostic accuracy of Neck Circumference-Height Ratio using Mild and Severe OSA as reference outcomes to predict Moderate OSA is shown in Table 4.2. A cutoff of ≥ 0.23 NHR was used to predict Moderate OSA using Mild and Severe as the reference outcomes (sensitivity: 57.89% (33.5 to 79.75); specificity: 66.86% (59.36 to 73.78). The positive predictive value (PPV) was 15.94% (10.91 to 22.7) and the negative predictive value (NPV) was 93.6% (89.52 to 96.16). The positive likelihood ratio was 1.75 (1.13 to 2.71) and the negative likelihood ratio was 0.63 (0.37 to 1.08). The AUC was determined as 0.6421 (0.52 to 0.77) and the accuracy yielded from the cutoff was 65.98% (58.85 to 72.61).

NHR CUT-OFF AND SEVERE OSA

Table 5.1 Diagnostic accuracy of Neck Circumference – Height ratio to predict Severe OSA

		Obstructive Sleep Apnea		Total
		Severe	Mild	
NHR	≥ 0.23	130	6	136
	< 0.23	33	6	39
	Total	163	12	175

Sensitivity	79.75% (72.76 to 85.64)	Positive LR	1.60 (0.90 to 2.82)
Specificity	50% (21.09 to 78.91)	Negative LR	0.40 (0.21 to 0.77)
PPV	95.59% (92.45 to 97.46)	AUC	0.6600 (0.49 to 0.83)
NPV	15.38% (8.73 to 25.69)	Accuracy	77.71% (70.82 to 83.65)

PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio

The diagnostic accuracy of Neck Circumference-Height Ratio using Mild OSA as reference outcomes to predict Severe OSA is shown in Table 5.1. A cutoff of ≥ 0.23 NHR was used to predict Severe OSA using Mild as the reference outcomes (sensitivity: 57.89% (33.5 to 79.75); specificity: 66.86% (59.36 to 73.78). The PPV was 15.94% (10.91 to 22.7) and the NPV was 93.6% (89.52 to 96.16). The positive likelihood ratio was 1.60 (0.90 to 2.82) and the negative likelihood ratio was 0.40 (0.21 to 0.77). AUC was determined as 0.6421 (0.52 to 0.77) and the accuracy yielded from the cutoff was 65.98% (58.85 to 72.61).

Table 5.2 Diagnostic accuracy of Neck Circumference – Height ratio to predict Severe OSA

		Obstructive Sleep Apnea		Total
		Severe	Mild and Moderate	
NHR	≥ 0.24	111	14	125
	< 0.24	52	17	69
	Total	163	31	194

Sensitivity	68.10% (60.35 to 75.17)	Positive LR	1.51 (1.01 to 2.25)
Specificity	54.84% (36.03 to 72.68)	Negative LR	0.58 (0.39 to 0.86)
PPV	88.80% (84.14 to 92.22)	AUC	0.6568 (0.55 to 0.76)
NPV	24.64% (18.12 to 32.57)	Accuracy	65.98% (58.85 to 72.61)

PPV, positive predictive value; NPV, negative predicted value; LR, likelihood ratio

The diagnostic accuracy of Neck Circumference-Height Ratio using Mild and Moderate OSA as reference outcomes to predict Severe OSA is shown in Table 5.2. A cutoff of > 0.24 NHR was used to predict Severe OSA using Mild and Moderate as the reference outcomes (sensitivity: 68.10% (60.35 to 75.17); specificity: 54.84% (36.03 to 72.68). The PPV was 88.80% (84.14 to 92.22) and the NPV was 24.64% (18.12 to 32.57). The positive likelihood ratio was 1.51 (1.01 to 2.25) and the negative likelihood ratio was 0.58 (0.39 to 0.86). The AUC was determined as 0.6568 (0.55 to 0.76) and the accuracy yielded from the cutoff was 65.98% (58.85 to 72.61).

Likewise, all evidence pointed to a positive relationship between NHR and OSA, which is consistent with our findings. In a retrospective study on 1,939 patients, Ho et al. (2016) utilized a baseline logistic regression model with a cut-off AHI of 5 events/hour for OSA to determine if BMI scores were predictive of OSA [6]. This baseline model includes an NHR cut-off. A later model has been utilized to assess the interaction between BMI score and AHI [6]. Similarly, linear models were then used to examine whether BMI score and NHR cut-off were predictive of AHI. The odds ratio and both positive and negative predictive values of having AHI >5, if NHR cut-off> 0.25 were calculated based on the X^2 table of the99 adult subjects. A significant NHR cut-off effect (P=0.012) was observed in the adult population using an NHR cut-off of 0.25 and an AHI cut-off of 5, with an odds ratio estimated in 18 patients with OSA with an NHR cut-off > 0.25. Although the odds ratio in adults was higher than in children (18 vs 3.47), the positive predictive value was only 25%, but the negative predictive value was elevated at 96%.The authors concluded that determining the NHR cut-off can be used as a simple screening method for OSA in children and adults, and when combined with other predictors, it may improve clinicians' ability to triage children and adults at risk for OSA for further evaluation with PSG [6]. These findings were also observed in another retrospective study conducted by Veeravigrom et al. (2017) determining OSA severity in a pediatric population with a sleep efficiency of < 80% [18]. Polysomnographic and anthropometric data were collected from 98 children (69 Male and 29 Female) aged 5–15 years who presented between September 2013 and August 2016.Results demonstrated that there was an insignificant cut-off point of NHR from the receiver operating characteristic (ROC) curve to predict OSA (OAHI ≥1.5/hour). The cut-off point 0.22 of NHR was selected from the ROC curve with AUC at 0.637 to predict moderate to severe OSA (OAHI ≥ 5/hour) at a sensitivity of 72.3% and specificity of 51%. NHR was found to be more predictive at 0.22 in children > 8 years of age with a sensitivity of 78.3% and specificity of 62%. The odds ratios of OAHI ≥ 5 and children over 8 years of age were 1.67 and 5.85, respectively, for NHR≥ 0.22 [18].

Unfortunately, there was limited evidence in the literature regarding an association between NHR cut-off and OSA.

CONCLUSION

The NHR cut-off demonstrated a moderate positive correlation with OSA, and NHR increases as the apnea-hypopnea index are increased (r=0.4610; p-value<0.001).

NHR cut-off of 0.23 is sufficient to predict severe OSA with a PPV of 95.59% and AUC of 0.66, but has poor diagnostic accuracy for mild and moderate OSA.

Moreover, the NHR cut-off may also be an integral tool to predict severe OSA.

LIMITATION OF THE STUDY

This is a retrospective study involving only patients who have been diagnosed with obstructive sleep apnea using a polysomnogram. Based on the clinical profile of each patient, a polysomnogram was only indicated and requested for patients who were highly suspected of having obstructive sleep apnea.

All of the patient's anthropometric measurements were taken by the patient's on-duty sleep technologists or sleep fellows in training, who alternated between shifts.

RECOMMENDATIONS

We propose conducting a comparative study to determine the diagnostic accuracy of the neck-circumference-height ratio and neck circumference in obstructive sleep apnea. A study to determine the diagnostic accuracy of the neck-circumference-height ratio in determining obesity hypoventilation syndrome (OHS).

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