Age-Related Neck Circumference in Habitually Snoring Children: A Potential Screening Tool for Obstructive Sleep Apnea in Children

Tayatorn Sudsuansee MD[1*]
Wiriya Nilprapa MD[1]
Worawan Rojanawong MD[2]

[1] Department of Pediatrics, Taksin Hospital, Bangkok, Thailand
[2] Department of Otolaryngology, Taksin Hospital, Bangkok, Thailand
* Corresponding author, e-mail address: tayatorn@gmail.com
Vajira Med J. 2022; 66(6): 369-80
http://dx.doi.org/10.14456/vmj.2022.38

Abstract

Objective: Neck circumference (NC) is becoming useful for various diseases in adults but not children. Due to a lack of normalized data. This study uses the normalized NC to compare with a patient's NC as a percentage (%NC) in habitually snoring children to distinguish obstructive sleep apnea (OSA) cases. The ratio of NC and adenoid thickness (NCAR) is hypothetically less in non-overweight OSA children. We proposed this ratio as a parameter to identify OSA in non-overweight children.

Methods: Habitually snoring children who underwent overnight pulse oximetry (overnight SpO_2)/ polysomnography (PSG) were eligible. Data gathering included an assessment of participants' body sizes and AT (from radiographs).

Results: Overall, there were 73 children (65% boys, median age 10.6 y (IQR 7.4-12.7), 52.1% of whom tested positive by either test. In addition, 58.9% of children underwent overnight SpO_2, and 20.9% tested positive. Among 30 children tested by PSG, confirmation of OSA diagnosis of varying severity was 96.7%. The positive and non-positive groups did not have statistically significant differences in %NC. In overweight children (n=40), there were no statistically significant differences of %NC between positive (n=27) and non-positive (n=13) results [94.9 (88.3-104.1) vs. 93.4 (89.3-104.4), p-value 0.669]. But the non-overweight group, positive children (n=19) had a statistically smaller median NCAR compared to non-positive children (n=11); 14.3 (12.7-14.9) vs. 16.2 (14.7-20.3), p-value=0.006. The proposed cut-off NCAR value in predicting non-positive tests in non-overweight children is more than 13.95, with a 47.4% sensitivity and 100% specificity. The positive predictive value is 100%, and the negative predictive value is 68.6%.

Conclusion: There was no statistically significant difference in %NC of the overall OSA vs. non-OSA children and the overweight OSA vs. non-OSA children. In the non-overweight group, NCAR was significantly smaller in positive children.

Keywords: neck circumference, habitual snoring, children, obstructive sleep apnea, screening

Received: 7 November 2022, **Revised:** 30 November 2022, **Accepted:** 1 December 2022

เส้นรอบวงคอตามเกณฑ์อายุในเด็กที่นอนกรนประจำมีศักยภาพเป็นเครื่องมือคัดกรองภาวะหยุดหายใจขณะหลับจากการอุดกั้นในเด็กหรือไม่

ทยาธร สุดสวนสี พ.บ.[1*]
วิริยา นิลประภา พ.บ.[1]
วรวรรณ โรจนวงศ์ พ.บ.[2]

[1] แผนกกุมารเวชกรรม โรงพยาบาลตากสิน กรุงเทพมหานคร ประเทศไทย
[2] แผนกหูคอจมูก โรงพยาบาลตากสิน กรุงเทพมหานคร ประเทศไทย
* ผู้ติดต่อ, อีเมล: tayatorn@gmail.com
Vajira Med J. 2022; 66(6): 369-80
http://dx.doi.org/10.14456/vmj.2022.38

บทคัดย่อ

วัตถุประสงค์: เส้นรอบวงคอ (NC) มีประโยชน์สำหรับโรคต่าง ๆ ในผู้ใหญ่แต่ไม่ใช่ในเด็กเนื่องจากขาดข้อมูลที่เป็นค่ามาตรฐานตามเกณฑ์อายุ การศึกษานี้ใช้ค่า NC ตามเกณฑ์อายุของเด็กเพื่อเปรียบเทียบกับค่า NC ของผู้ป่วยเด็กนอนกรนประจำเป็นร้อยละ (%NC) เพื่อแยกภาวะหยุดหายใจขณะหลับจากการอุดกั้น (OSA) นอกจากนี้ในเด็ก OSA ที่ไม่มีโรคอ้วน อัตราส่วนของ NC กับความหนาของต่อมอะดีนอยด์ (NCAR) อาจใช้เป็นพารามิเตอร์ที่ช่วยแยกเด็ก OSA ได้ ผู้วิจัยจึงทำการศึกษาอัตราส่วนนี้ในเด็กกลุ่มนี้ด้วย

วิธีดำเนินการวิจัย: เด็กนอนกรนประจำอายุ 5-15 ปี ที่ได้รับการตรวจความอิ่มตัวก๊าซออกซิเจนในเลือดข้ามคืน (overnight SpO_2) หรือตรวจการนอนหลับ (polysomnography) จะถูกวัดขนาดร่างกาย ความยาวรอบคอ และความกว้างของต่อมอะดีนอยด์จากภาพรังสี

ผลการวิจัย: เด็กนอนกรนประจำทั้งหมด 73 คน (เพศชาย ร้อยละ 65 มัธยฐานอายุ 10.6 ปี (IQR 7.4-12.7) โดยร้อยละ 52.1 ของเด็กทั้งหมดให้ผลบวกต่อการตรวจวิธีใดวิธีหนึ่ง มีเด็ก ร้อยละ 58.9 ของทั้งหมดตรวจโดยวิธี overnight SpO_2 และให้ผลบวก ร้อยละ 20.9 ในจำนวนเด็ก 30 คนที่ทดสอบโดย PSG ยืนยันการวินิจฉัย OSA ร้อยละ 96.7 โดย ร้อยละ (%NC) ในเด็กทั้งหมด กลุ่มที่ผลการตรวจเป็นบวกและไม่เป็นบวกไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ เมื่อพิจารณาเฉพาะเด็กเริ่มอ้วน (overweight, n=40) ไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติของร้อยละ (%NC) ระหว่างกลุ่มที่ผลเป็นบวก (n=27) กับไม่เป็นบวก (n=13) [94.9 (88.3-104.1) vs. 93.4 (89.3-104.4) ค่า p=0.669] แต่ในกลุ่มที่น้ำหนักตามเกณฑ์ เด็กที่ผลเป็นบวก (n=19) มีค่ามัธยฐาน NCAR น้อยกว่ากลุ่มที่ไม่เป็นบวก (n=11) อย่างมีนัยสำคัญทางสถิติ (n=11); 14.3 (12.7-14.9) vs. 16.2 (14.7-20.3), p-value=0.006 การทดสอบ ROC ของค่า NCAR พบว่า ค่า NCAR ที่มากกว่า 13.95 สามารถทำนายโอกาสที่ผลตรวจจะไม่เป็นบวกในเด็กที่น้ำหนักตามเกณฑ์ได้โดยมีความไวร้อยละ 47.4 และความจำเพาะร้อยละ 100 ค่าการทำนายเชิงบวกคือ ร้อยละ 100 และค่าการทำนายเชิงลบคือร้อยละ 68.6 ซึ่งเป็นกลุ่มที่น่าจะได้ประโยชน์จากการตรวจ PSG มากกว่า overnight SpO_2

สรุป: ไม่พบความแตกต่างที่มีนัยสำคัญทางสถิติของร้อยละ (%NC) ในเด็กระหว่างกลุ่มที่เป็น OSA และไม่เป็น OSA ทั้งในภาพรวมและเฉพาะในกลุ่มเด็กอ้วน แต่ในเด็กที่ไม่อ้วน เด็กที่ให้ผลการตรวจเป็นบวกจะมี NCAR เล็กกว่าอย่างมีนัยสำคัญทางสถิติ

คำสำคัญ: เส้นรอบวงคอ นอนกรน เด็ก ภาวะหยุดหายใจขณะหลับจากการอุดกั้น คัดกรอง

วันที่รับบทความ 7 พฤศจิกายน 2565 **วันแก้ไขบทความ** 30 พฤศจิกายน 2565 **วันตอบรับบทความ** 1 ธันวาคม 2565

Introduction

Sleep-related breathing disorders are clinically diverse disorders cover the spectrum from habitual snoring, upper airway resistance syndrome, obstructive hypoventilation, to obstructive sleep apnea (OSA). In Thailand, the prevalence of habitual snoring in children is 6.9-8.5% and OSA diagnosis is 0.7-1.3%[1-2]. However, a study of the OSA prevalence in children undergoing polysomnography (PSG) at a university hospital in Thailand was 92.7%[3]. The guidelines for diagnosis and treatment of snoring children who have enlarged tonsils and/or adenoids are available from the Thai Society of Pediatric Respiratory and Critical Care. According to the guidelines, the gold standard for OSA diagnosis is PSG, and the screening method is overnight pulse oximetry (overnight SpO_2)[4]. The guideline also recommended overnight SpO_2 as an alternative tool for OSA diagnosis because this test has a high positive predictive value. However, patients who test negative should further perform PSG because it has a high false negative rate of 47%[5].

Recently, more diseases are requiring the measurement of neck circumference (NC). In adults, increased NC is associated with OSA[6]. In women, and men who had NC greater than 16 and 17 inches, respectively, the risk of OSA increased[7]. A screening test called "STOP-BANG" in adult patients also used NC, body mass index (BMI), and symptoms[8]. In 2016, the NC was used in terms of the NC to height ratio (NHR) to assess OSA risk in pediatric and adult patients[9]. Results showed that children with an NHR > 0.25 (corrected for BMI z-score) had a 3.47-fold increased risk of OSA compared with an 18-fold increased risk of OSA in adults. Researchers speculated that this was due to the lack of age-related normalized NC in children. The problem with implementing the NC in children is that not only does the NC change with nutritional status, but also, the nature of growth of the NC in children makes implementation difficult.

In Thailand, normalized NC has already been made available for children of all ages and sexes[10]. If there is a difference between normalized NC of OSA and non-OSA children, this has potential as a screening tool for OSA. We hypothesized that overweight children with OSA tend to have greater NC than normal-weight children of the same age and are more likely than NC in overweight children without OSA. In contrast to non-overweight children whose NC should be average, the enlarged adenoids and tonsils are likely to cause OSA. When calculating the ratio between their average NC and their large adenoid thickness (AT) on radiographs, the values should be lower than in non-OSA children (who are supposed to have smaller adenoids). If the results are consistent with these assumptions; we could use the NC as an appropriate and cost-effective tool to select snoring children for PSG.

Methods

The primary objective of this cross-sectional study was to compare the mean age-related NC (%NC) of children with habitual snoring aged 5-15 years with and without OSA at Taksin Hospital, Bangkok, in 2018-2019. Secondary objectives were to compare the mean %NC in overweight children with and without OSA and compare the mean NC to the radiographic adenoid thickness (NCAR) ratio in non-overweight children with and without OSA. This research calculates the sample from the formula;

$$n \geq (1+r/r)(Z_{1-\alpha/2} + Z_{1-\beta})^2 / d^2 + Z^2_{1-\alpha/2}/2(1+r)$$

While n=sample size, r=sample size ratio assigned as 2, d=expected sample assigned as 0.8 (from the results of similar studies, $Z_{1-\alpha/2}$=two-sided Z value assigned as 1.96, $Z_{1-\beta}$=power assigned as 80%. Dependent variables are OSA occurrences either diagnosed by PSG or overnight SpO_2 monitoring[13]. Independent variables are age, sex, weight, height, socioeconomic status, household smoking, enlarged tonsils, chronic sinusitis, NC and thickness of adenoid glands from radiographs. The Bangkok Metropolitan Administration Human Research Ethics Committee approved the study protocol. Consent from parents or guardians was usually a prerequisite for participants. Adolescents received

the written assent forms. The patient's demographic data collection included age, sex, household smoking, physician's diagnosis of adenotonsillar hypertrophy, and physician's diagnosis of chronic sinusitis.

Inclusion criteria included children aged 5-15 years who had habitual snoring (history of snoring >3 nights/week) or breathing problems during sleep for whom a physician considered additional evaluation by performing either an overnight SpO_2 or PSG test. The choice of testing method for each participant is at the physician's discretion. This is greatly influenced by the patient's health insurance coverage.

Exclusion criteria: 1. suspected central apnea or central hypoventilation; 2. severe neuromuscular disorders (e.g., muscular dystrophy, cerebral palsy); 3. chronic pulmonary disease requiring home oxygen therapy; 4. facial proportions abnormalities such as Down syndrome; 5. inherited disorders of muscle tone such as Prader-Willi syndrome; and 6. CPAP titration patients with a tracheostomy tube or PSG after tracheostomy decannulation.

Measurements

On the overnight SpO_2 or PSG examination date, nurses who trained for the NC measurement measured the body sizes of participants, including weight (by Tanita® WB-100), height (by Seca® 216), and NC (by medical plastic measuring tape). A radiograph of the neck lateral soft tissue technique was obtained on the same date for measuring adenoid thickness (AT). Weight was measured with light clothing and without shoes. The comparison of patient weight and the weight according to the height standard for Thai children[11] is the %ideal weight [%ideal weight = patient weight x 100/ weight standard at P50]. The percentage of patient height compared with P50 of children of the same age is the %median H/A [%median H/A = patient height x 100/height standard at P50].

NC is the length around the base of the neck above the clavicle (according to the standard measurement of body proportions in Thai children)[10]. The age-related neck circumference (%NC) refers to the determined NC values calculated as a percentage compared with the NC of normal children of the same age and gender according to the formula [%NC = (measured NC x 100)/standard NC of children]. NCAR is the ratio between the measured NC and the thickness of the adenoids on radiographs. Adenoid thickness (AT) is the thickness of adenoids from the perpendicular to the most distant part (convex) of the gland to the line joining the upper end of the pterygomaxillary fossa and the tip of the anterior margin of the atlas bone[12]. The Digital Radiographic Viewer (PACS™) is used to measure AT using the measurement features provided in the software by the research project leader.

Obstructive sleep apnea (OSA) in children is a condition in which a child has complete obstruction of the upper airway during sleep so that air cannot enter through the nose or mouth. Respiratory flow measured by the thermistor has decreased by 90% or more in at least two respiratory cycles, accompanied by dyspnea and paradoxical movements of the chest and abdomen[13]. The PSG in this study, using Compumedic™Somte, consisted of standard full night PSG measurements in which trained sleep technicians monitored the patients' condition. The trained physicians evaluate polysomnograms regarding pediatric OSA diagnostic criteria[13]. Overnight SpO_2 is the oxygen saturation monitoring during sleep for at least 6 hours (using the Bitmos™ sat 805). The SpO_2 tracing was graphed using Satview™ software version 1.1.9 and interpreted using McGill oximetry scores[14]. The OSA diagnostic criteria used in this study were the apnea-hypopnea index (AHI) $\geq$ 1.5 events/hour (from PSG) or the oximetry score > 1 (from overnight SpO_2). The severities of OSA in children classified by AHI are AHI 1.5 to < 5 events/hour = mild OSA, AHI 5-10 events/hour = moderate OSA, and AHI > 10 events/hour = severe OSA[15]. If overnight SpO_2 results are negative or inconclusive and further PSG testing is required, this further testing involves another visit for analysis (using the same case number, the body sizes are

measured again and analyzed separately for each OSA test). Pediatric overweight diagnosis is made for a child with a percentage of %ideal weight ≥ 120%[16].

Statistical Analysis

All study participants with adequate sleep duration according to sleep monitoring standards were analyzed. However, this study did not find participants with insufficient sleep duration to be excluded. Most of the variables in this study followed a non-normal distribution by the Kolmogorov-Smirnov test, the reported results were given in term of the median (interquartile range (IQR): 25th to 75th percentile). Researchers used the Mann-Whitney U or Kruskal Wallis test for continuous variables comparison, and the test for categorical variables was the chi-square test. The analysis of correlation in this study was conducted via the Spearman test. The ROC analysis was for determining the optimal cutoff value from the potential variables. P values were two-sided and statistical significance was assumed at $p < 0.05$. The computer software for data analysis is SPSS for Windows version 16.0.

In data analysis, the researchers classify patients who perform overnight SpO_2 into groups of those who test positive and those who do not test positive (including inconclusive and negative patients). The rationale is that patients who do not give a positive result still need to be tested further with PSG because the overnight SpO_2 test has a high false negative value[5].

Results

A total of 73 Thai children with habitual snoring participated in the study; 65% were boys with a median age of 10.6 years. (IQR: 7.4-12.7) The total number of patients who tested positive for either PSG or overnight SpO_2 was 52.1%. There were 43 children (58.9%) who underwent overnight SpO_2. For children tested by overnight SpO_2 testing, 53.5% were negative, and 20.9% were positive. Among 30 children tested by PSG, confirmation of OSA diagnosis of varying severity was 96.7%. In the PSG group, only one patient had negative results (3.3%). The demographic and clinical characteristics of the patients tested with overnight SpO_2 and PSG are shown in Table 1. The overnight SpO_2 patients had a higher percentage of family history of household smoking than the PSG group. There is no statistically significant difference in demographic data between overweight children with and without OSA. In non-overweight participants, positive test group (n=22) significantly has more proportion of negative household smoking (90.9%) than non-positive patients (54.5), p-value 0.027.

Overall, the non-positive patients (n=35) comprised the negative PSG patients (n=1), negative overnight SpO_2 patients (n=23), and inconclusive overnight SpO_2 patients (n=11). Both groups showed no statistically significant difference in terms of AT, %ideal weight, %median H/A, BMI, %NC, and NCAR, as shown in Table 2. None of the non-positive overnight SpO_2 subjects proceed to perform PSG testing during the study period.

There were no statistically significant differences in the overnight SpO_2 group between various oximetry scores and the body size variables. Similarly, there were no statistically significant differences in the PSG group between the OSA severity by PSG and the body size variables. (table 3). However, there was a correlation between some anthropometric data and nadir SpO_2 or PSG indices. Nadir SpO_2 of all patients from both tests (PSG and overnight SpO_2) was statistically inversely related to AT. Meanwhile, AHI and RDI had a linear correlation with %median H/A and %NC, and CAI had a linearly inverse correlation with %ideal weight andBMI (table 4).

In the correlated variables plotted in the scatterplots, the variables with the highest r-squared (r^2) values were AHI vs. %NC ($r^2 = 0.226$) and RDI vs. %NC ($r^2 = 0.228$). (figure 1) The scatterplots between %median H/A vs. AHI and RDI had r^2 values of 0.106 and 0.107, respectively. The CAI was inversely related to the %ideal weight and BMI, with the r^2 values from the scatterplot being 0.018 and 0.037, respectively. The AT vs. nadir SpO_2 had r^2 values of 0.109.

Table 1 Demographic and clinical characteristics of patients who underwent overnight SpO_2 and PSG testing

Variables[a]	Overnight SpO_2 (n=43)		PSG (n=30)		p-value
Male (%)	67.4%		63.3%		0.804
Household smoker (%)	39.5%		16.7%		0.042
ATH diagnosis (%)	76.7%		73.3%		0.787
Chronic sinusitis diagnosis (%)	2.3%		3.3%		1.000
Age (year)	9.9 (8.1-11.3)		11 (6.7-13.3)		0.641
%ideal weight	128 (106-159)		131.5 (102.5-167.8)		0.340
%median H/A	102 (97-105)		101 (95.8-104)		0.777
BMI	20.6 (17.3-28.4)		23.4 (16.22-29.7)		0.713
AT	1.8 (1.6-2.1)		1.7 (1.3-2.3)		0.224
%NC	89.5 (84.1-96.4)		92.5 (81-99.3)		0.936
NCAR	16.2 (14.4-19.2)		16.7 (14.3-20.4)[b]		0.964
Sleep architecture • TST (min) • Latency (min) • N1 (% of TST) • N2 (% of TST) • N3 (% of TST) • REM (% of TST) • Efficiency (%)			469.5 (422-491.8) 11.5 (4.8-19.3) 4.5 (3-8.75) 46.5 (42.8-54.3) 26 (17.8-33) 18 (16.8-21) 92.7 (90.3-95.6)		
Events	Oximetry Score 1 Oximetry Score 2 Oximetry Score 3 Oximetry Score 4	79.1% 11.6% 4.7% 4.7%	Arousal index RDI CAI AHI	37.2 (24.5-49.7) 8.9 (4.4-16.1) 0.4 (0-1.25) 8.3 (3.8-16)	
Nadir SpO_2 (%)	91 (86.8-93)		89 (85.8-92)		0.111
ETCO2 > 45 mmHg (% of TST)			0.14±0.6[c]		
Diagnosis	Negative Inconclusive Positive	53.5% 25.6% 20.9%	1^0 snoring Mild OSA Moderate OSA Severe OSA	3.3% 30% 30% 36.7%	

[a]Numbers are in median (IQR: 25-75th percentile), [b]n=25 (Five patients had a history of adenotonsillectomy, and adenoid thickness is 0 mm).
[c]2 patients had ETCO2 > 45 of 1 and 2.6% of TST, Numbers are in mean+S.D. (ATH = adenotonsillar hypertrophy, TST = total sleep time, RDI = respiratory disturbance index, CAI = central apnea index, AHI = apnea-hypopnea index; all indices are in events/h)

Table 2 Comparisons of body sizes in participants according to test results in each method

Variables[a]	Positive			Non-positive			p-value		
	Overall (n=38)	Overnight SpO_2 (n=9)	PSG (n=29)	Overall (n=35)	Overnight SpO_2 (n=34)	PSG (n=1)	Overall (n=73)	Overnight SpO_2 (n=43)	PSG (n=30)
AT (cm)	1.76 (1.6-2.32)	2.1 (1.7-2.5)	1.64 (1.4-2.1)	1.79 (1.62-2.08)	1.78 (1.6-2)	2.3	0.685	0.161	0.533
%IBW	138 (102-172)	146 (108-184.5)	130 (102-165)	128 (106-158)	124 (105.7-151.3)	177	0.623	0.298	0.333
%H/A	101 (96-104)	100 (96-105.5)	101 (95.5-104)	102 (100-105)	102 (99.5-105)	102	0.205	0.502	0.867
BMI	24.6 (16.3-31.4)	27.85 (17.2-33.7)	23.2 (16.2-29.2)	20.6 (17.3-27.9)	20.6 (17.2-27.8)	34.6	0.600	0.418	0.267
%NC	93.5 (81.7-100.1)	93.5 (79.8-103.4)	90.7 (80.8-100.1)	89.5 (84.4-96.4)	89.3 (84.3-96.4)	94.6	0.727	0.714	0.733
NCAR (n=68)[b]	16.6 (14.3-19.5)	16.1 (13.8-17)	16.9 (14.3-20.5)	16.2 (14.7-19.6)	16.5 (14.6-19.8)	15.8	0.581	0.309	0.88

[a]Numbers are in median (IQR: 25th-75th percentile) [b]5 positive participants had an adenoid thickness of 0 mm. due to post-adenotonsillectomy (All were in the PSG group). (%IBW is %ideal weight, %H/A is % median H/A)

Table 3 Anthropometric variables between various overnight SpO_2 and PSG outcomes

Variables[a]	Overnight SpO_2					PSG				
	Ox. Score 1 (n=34)	Ox. Score 2 (n=5)	Ox. Score 3 (n=2)[b]	Ox. Score 4 (n=2)[b]	p-value	1^{o} snoring (n=1)	Mild OSA (n=9)	Moderate OSA (n=9)	Severe OSA (n=11)	p-value
AT (cm)	1.78 (1.61-2.04)	1.68 (1.47-2.2)	2.37±0.33	2.35±0.48	0.115	2.3	1.58 (0-2)	1.51 (0.7-1.8)	1.81 (1.6-2.4)	0.158
%IBW	124 (105.8-151.3)	173 (108-193)	122.5±3.3	149±4.7	0.539	177	115 (92.5-142.5)	133 (107.5-170.5)	144 (103-178)	0.185
%H/A	102 (99.5-105)	96 (96-105)	97.5±3.5	108.5±4.9	0.107	102	98 (93.5-101.5)	101 (95-107)	103 (100-104)	0.506
BMI	20.6 (17.2-27.8)	27.9 (16.9-43.9)	22.7±8.3	25±9.7	0.817	34.6	19 (14.2-25.3)	23.6 (17.6-30.5)	25.3 (16.2-30.9)	0.149
%NC	89.3 (84.3-96.8)	87.1 (78.9-103.4)	86.1±1.2	103.3±1.4	0.498	94.6	77.9 (76.5-96)	90.7 (87.9-99.7)	94.6 (89.8-101.7)	0.109
NCAR[c]	16.5 (14.6-19.8)	16.6 (14.7-22.2)	13.9±4.7	14.4±0.1	0.440	15.8	14.5 (12.4-16.8)	18.9 (17.2-21.6)	16.25 (14.3-20.6)	0.156

[a]Numbers are in median (25th-75th percentile) [b]Numbers are in mean±S.D. [c]5 patients in this group had a history of adenotonsillectomy, and adenoid thickness is 0 mm. (Ox. Score = oximetry score, RDI = respiratory disturbance index, CAI = central apnea index, AHI = Apnea-hypopnea index; all indices are in events/h)

Table 4 Correlation coefficients (p-value) between nadir SpO_2 or PSG indices and body sizes

	Nadir SpO_2 (N=73)	AHI (n=30)	RDI (n=30)	CAI (n=30)	Arousal index (n=30)
Adenoid thickness	-0.259 (0.027)	0.298 (0.109)	0.323 (0.082)	-0.059 (0.757)	0.338 (0.068)
%ideal weight	-0.198 (0.092)	0.346 (0.061)	0.347 (0.061)	-0.401 (0.028)	0.141 (0.458)
%median H/A	-0.031 (0.792)	0.374 (0.042)	0.371 (0.044)	-0.199 (0.293)	0.142 (0.454)
BMI	-0.185 (0.118)	0.345 (0.062)	0.346 (0.061)	-0.470 (0.009)	0.141 (0.458)
%NC	-0.075 (0.528)	0.465 (0.01)	0.467 (0.009)	-0.279 (0.135)	0.201 (0.287)
NCAR	0.186 (0.129)	0.053 (0.801)	0.054 (0.796)	-0.098 (0.641)	0.057 (0.786)

(AHI=Apnea-hypopnea index, RDI=respiratory disturbance index, CAI = central apnea index)

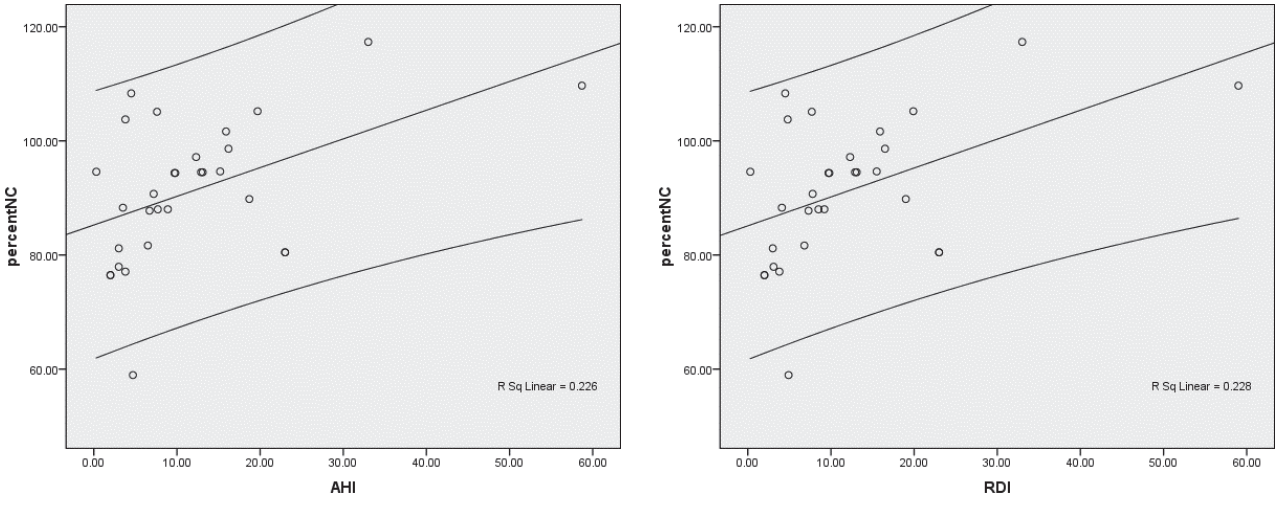

Figure 1 Correlation between %NC vs. AHI (left) and RDI (right)

The comparison of %NC in the overweight group (n=40), there were no statistically significant differences between positive (n=27) vs. non-positive (n=13) results [94.9 (88.3-104.1) vs. 93.4 (89.3-104.4), p-value 0.669]. But in the non-overweight group, positive children (n=19) had a statistically smaller median NCAR compared to non-positive children (n=11); 14.3 (12.7-14.9) vs. 16.2 (14.7-20.3), p-value 0.006. (3 non-overweight children were excluded from this analysis because they underwent adenotonsillectomy before this follow-up PSG. They had no residual radiographic adenoid hypertrophy).

ROC analysis of NCAR for predicting non-positive tests in the non-overweight children had the area under the curve of 0.799, p-value 0.007 (95%CI 0.64-0.958). The proposed cut-off NCAR value in predicting non-positive tests in non-overweight children is more than 13.95, with 100% specificity and 47.4% sensitivity. The positive and negative predictive values are 100% and 68.6%, respectively.

Discussion

This study found no statistically significant differences in body size between positive and non-positive patients (either PSG test or overnight SpO_2 test). However, there were correlations

between some anthropometric parameters and OSA indices or nadir SpO_2. For %NC in overweight children, we found no statistically significant differences between positive and non-positive patients. For NCAR in non-overweight children, we found that positive children statistically had a smaller median NCAR than non-positive children. According to this study, NCAR > 13.95 predicted non-positive tests in non-overweight children with high specificity and moderate sensitivity. When considering patients in the overnight SpO_2 group, there are no statistically significant differences between oximetry scores and body sizes. However, we found a correlation between AT and nadir SpO_2 in this group with a coefficient of -0.525 (p-value 0.0003). The reason for the non-significance between oximetry scores and AT is possibly due to the components of these scores. The oximetry scores comprise the nadir SpO_2 and the frequency of the SpO_2 drop. AT itself may not correlate with the latter factor. As with the PSG cohort, we did not find a statistically significant difference between OSA patients of varying severity and patients with primary snoring. However, there was only one in the primary snoring group in this study. When we excluded the primary snoring case, the body sizes (BMI, %ideal weight, and %NC) tended to increase as the severity increased. In particular, the %NC had the smallest p-value of 0.109, and %NC was statistically correlated to AHI and RDI.

Two previous studies had the same results as this study[17-18]. Both studies found no statistically significant difference in NC between OSA and non-OSA groups. However, the average age of patients from these two studies were different; one studied early school-age children[18], and the other studied adolescents[17]. Instead, they found that some ratios were significantly different between the OSA and non-OSA groups; one was the neck-to-height ratio[18], and the other was the waist-to-height ratio[17]. We hypothesize that a single parameter such as length, height, or circumference is not sufficiently sensitive to differentiate OSA children from non-OSA. In 2016, the use of NHR to assess OSA risk in pediatric and adult patients[9] found that children with an NHR > 0.25 (corrected for BMI z-score) had an increased risk of OSA but less than in adults (3.47- vs. 18-fold). Researchers speculated that this was due to the lack of age-related normalized NC in children. This study used age-related normalized NC to compare but failed to achieve the same result. The reason is probably that age-related normalized NC in this study is not a BMI z-score-corrected value.

In overweight children, %NC was not statistically significantly different between the OSA and non-OSA groups. Most of the past studies used raw NC values to determine the risk of OSA. One study found that children with NC > 95th percentile increased their risk of OSA statistically by 1.7 times, but the effect was insignificant for those under 12 years old[19]. In this study, we did not find the same result because when using the NC cut-off at the 95th percentile, this study found a relative risk of 1.09 (p-value 0.605, 95%C.I. 0.78-1.52). The reason is that children in this study were of a lower mean age than the mentioned study. The effect of NC in younger children might not be as pronounced as in the older group. In pre-teens with OSA, enlarged adenoids may play a greater role than overweight. In the non-overweight group, the children who tested positive had a statistically smaller median NCAR compared to the non-positive group. This study is the first to use NCAR to study its relationship with OSA. The ratios used in the previous studies were neck-to-waist (NWR)[17, 20] and neck-to-height (NHR) ratios[9]. Both ratios (NWR and NHR) work better in adolescents than in younger children, and in overweight children than non-overweight ones. Therefore, we were interested in variables among non-overweight children, so we proposed NCAR. However, we also analyzed NHR and NWR in this population and found no statistically significant differences between positive and non-positive patients. The reason might be that children in this study were predominantly early adolescents whose morphological changes were not similar to those in older adolescents who have had growth spurts

already. There was a statistically significant inverse relationship between CAI vs. %ideal weight and BMI. As in the previous study[21], central sleep apnea (CSA) incidence is higher than in adults, and overweight children had a lower incidence of CSA than non-overweight children. The same was true for this study.

This study is a pioneer study using NCAR in non-overweight children. OSA in children has a complex pathogenesis, especially in the overweight group. The previously mentioned studies have unsuccessfully found a single anthropometric parameter in identifying the OSA cases in children. In contrast to using ratios, the results are more promising. The rationale for using NCAR in the non-overweight group is also reasonable (the small neck circumference of the non-overweight divided by the thicker adenoids of suspected OSA cases, the result should be smaller than the non-OSA). We therefore strengthen the argument that NCAR has potential for screening OSA.

The possible cause of the failure to demonstrate statistically significant differences between positive and non-positive groups is that we have limited number of sample size and we found only one negative PSG subject to compare between groups. In Thailand, PSG is a test mostly performed in patients in which there is a high suspicion of OSA. Therefore, this selection bias give higher chances of a positive result than in the general population. And because overnight SpO_2 testing is more convenient than PSG testing and tends to be used more, especially in resource-constrained countries, then the researchers included diagnostic criteria of OSA from either overnight SpO_2 or PSG. As a result, the results of this study may not be directly compared with other studies in terms of OSA incidence. Even though overnight SpO_2 is often the preferred method for OSA screening in this institution due to its feasibility and cost-effectiveness, there will be a group of patients who have inconclusive results and need additional PSG testing. It would be great to have a variable(s) that can predict the probability of OSA in this group of patients and allow us to choose PSG instead of overnight SpO_2 testing. Unfortunately, this study showed no helpful parameter related to body size except the NCAR for non-overweight snoring children. The hypothesis of NCAR is reasonable for non-overweight children, but these populations were both overweight and non-overweight mixed in equal proportions, so the discriminant power of this value was not good in this case. The limitation of NCAR is in a patient who underwent adenoidectomy because it uses the thickness of the adenoid gland as the denominator, which is equal to zero, making it impossible to use in this group of patients who, on the basis of common sense, are unlikely to develop OSA due to this cause. Only nine children (12.3%) in this study were under six years of age, which is the age at which adenotonsillar hypertrophy is prominent and results in OSA[22]. We selected these children for analysis and found no statistically significant differences between all anthropometric variables and OSA test results. The explanation may be that the small number of cases in this age group may not be able to demonstrate the importance of AT in this study. Further studies in the 3–6-year age group should yield more reliable results. In this study, the location of the NC measurement was at the base of the neck. This location is the reference from the standard NC measurement[10]. Comparing the results of this study with others may need to consider this as a limitation.

In summary, anthropometric measurement as isolated value in “habitually snoring children” seems invaluable for the screening OSA. The utility of such parameters in ratios (such as NCAR, NWR, NHR) has greater potential as a screening tool. A well-designed study to validate NCAR utilization is necessary before generalizability in habitually snoring children. Greater sample sizes, especially in the PSG test group, are necessary to increase the number of negative cases for comparison. Alternatively, the randomization between PSG and overnight SpO_2 to evenly distribute the negative subjects in both groups might provide more reliable conclusions. Finally, future research should consider the relevance of puberty as a factor.

Conclusion

There was no statistically significant difference in %NC of the OSA and non-OSA children. In overweight children, there was also no statistically significant difference in %NC between positive and non-positive groups. In the non-overweight group, NCAR was significantly smaller in positive children than in non-positive children.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgement

None

References

1. Anuntaseree W, Kuasirikul S, Suntornlohanakul S. Natural history of snoring and obstructive sleep apnea in Thai school-age children. Pediatr Pulmonol 2005;39(5):415-20.
2. Anuntaseree W, Rookkapan K, Kuasirikul S, Thongsuksai P. Snoring and obstructive sleep apnea in Thai school-age children: prevalence and predisposing factors. Pediatr Pulmonol 2001;32(3):222-7.
3. Veeravigrom M, Desudchit T. Prevalence of sleep disorders in Thai children. Indian J Pediatr 2016;83(11):1237-41.
4. Preutthipan A, Sritippayawan S, Kuptanon T. Thai guideline for childhood obstructive sleep apnea [internet]. 2015 [cited 2018 May 8]. Available from:https://drive.google.com/file/d/1UQ8NNd_ZRCFyFAdXn4hi0IfvwPEbym3t/view
5. Brouillette RT, Morielli A, Leimanis A, Waters KA, Luciano R, Ducharme FM. Nocturnal pulse oximetry as an abbreviated testing modality for pediatric obstructive sleep apnea. Pediatrics 2000;105(2):405-12.
6. Stradling JR, Crosby JH. Predictors and prevalence of obstructive sleep apnoea and snoring in 1001 middle aged men. Thorax 1991;46(2):85-90.
7. Epstein LJ, Kristo D, Strollo PJ Jr, Friedman N, Malhotra A, Patil SP, et al. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. J Clin Sleep Med 2009;5(3):263-76.
8. Chung F, Yegneswaran B, Liao P, Chung SA, Vairavanathan S, Islam S, et al. STOP questionnaire: a tool to screen patients for obstructive sleep apnea. Anesthesiology 2008;108(5):812-21.
9. Ho AW, Moul DE, Krishna J. Neck circumference-height ratio as a predictor of sleep related breathing disorder in children and adults. J Clin Sleep Med 2016;12(3):311-7.
10. Srikanjana J. Thai children standard sizes [internet]. 2013 [cited 2018 May 3]. Available from: http://www.research.rmutt.ac.th/wp-content/uploads/2013/03/5-Thai-Children-Standard-Sizes-Dr.Srikanjana.pdf.
11. Ministry of Public Health. Standard growth chart for children [internet]. 2021 [cited 2021 Dec 15]. Available from:https://nutrition2.anamai.moph.go.th/th/kidgraph
12. Jain A, Sahni JK. Polysomnographic studies in children undergoing adenoidectomy and/or tonsillectomy. J Laryngol Otol 2002;116(9):711-5.
13. Berry RB, Budhiraja R, Gottlieb DJ, Gozal D, Iber C, Kapur VK, et al. Rules for scoring respiratory events in sleep: update of the 2007 AASM Manual for the Scoring of Sleep and Associated Events. Deliberations of the sleep apnea definitions task force of the American Academy of Sleep Medicine. J Clin Sleep Med 2012;8(5):597-619.
14. Nixon GM, Kermack AS, Davis GM, Manoukian JJ, Brown KA, Brouillette RT. Planning adenotonsillectomy in children with obstructive sleep apnea: the role of overnight oximetry. Pediatrics 2004;113(1 Pt 1):e19-25.
15. Beck SE, Marcus CL. Pediatric polysomnography. Sleep Med Clin 2009;4(3):393-406.
16. Rattanachuek S, Thaweekul P, Iamopas O, Suthutvoravut U. Thai guideline for childhood obesity [internet]. 2014 [cited 2018 Oct 18]. Available from: https://drive.google.com/file/d/1qIHLECHIYzwobw3sj5ChRcLnFKz4lR1X/view

17. Narang I, Al-Saleh S, Amin R, Propst EJ, Bin-Hasan S, Campisi P, et al. Utility of neck, height, and tonsillar size to screen for obstructive sleep apnea among obese youth. Otolaryngol Head Neck Surg 2018;158(4):745-51.
18. de Sousa Caixêta JA, Saramago AM, de Cácia Pradella-Hallinan ML, Moreira GA, Tufik S, Fujita RR. Waist-to-height ratio distinguish obstructive sleep apnea from primary snoring in obese children. Sleep Breath 2015;19(1):231-7.
19. Katz S, Murto K, Barrowman N, Clarke J, Hoey L, Momoli F, et al. Neck circumference percentile: a screening tool for pediatric obstructive sleep apnea. Pediatr Pulmonol 2015;50(2):196-201.
20. Katz SL, Vaccani JP, Barrowman N, Momoli F, Bradbury CL, Murto K. Does neck-to-waist ratio predict obstructive sleep apnea in children? J Clin Sleep Med 2014;10(12):1303-8.
21. Chou CH, Kang KT, Weng WC, Lee PL, Hsu WC. Central sleep apnea in obese children with sleep-disordered breathing. Int J Obes (Lond) 2014;38(1):27-31.
22. Gulotta G, Iannella G, Vicini C, Polimeni A, Greco A, de Vincentiis M, et al. Risk factors for obstructive sleep apnea syndrome in children: state of the Art. Int J Environ Res Public Health 2019;16(18):3235.