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Neck circumference - A simple and valid screening tool for obesity in school children

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Abstract

Background/Aim: Childhood obesity is on a rise worldwide with an estimated prevalence of over 8% and 6% in boys and girls, respectively. Being a forerunner of adult obesity and its consequences, this has to be detected earlier and appropriate interventions instituted timely for better health outcomes. Neck Circumference is a simple screening tool for detecting obesity. This study aimed to find out the correlation between neck circumference and body mass index (BMI) and measures of central obesity like waist circumference (WC), hip circumference (HC), and waist-hip ratio (WHR). It also tried to find out the age and gender-specific cut-off values for overweight and obesity in schoolchildren aged 6 to 16 years.
Methods: This was a cross-sectional observational study conducted in the primary and secondary schools of a sub-urban region of south Kerala, India. The anthropometric measurements, including weight, height, neck circumference, waist and hip circumferences of children aged 6-16 years who satisfied the inclusion criteria were obtained by health professionals, and their BMIs were compared with WHO standards to detect overweight and obesity. The correlation between BMI and NC, sensitivity, and specificity of NC in detecting overweight and obesity, and age-related cut-off values of NC were calculated using appropriate statistical methods. The correlation of NC with indicators of central obesity like waist circumference, hip circumference, and waist-hip ratio were also determined.
Results: A total of 1797 students were studied. Neck circumference showed a significant positive correlation (r = +0.6 to +0.8, P<0.001) with body mass index, waist circumference, and hip circumference but not with waist-hip ratio (r =+.3 to -.2). In ROC analysis, age-specific cut-off values of NC for obesity and overweight were obtained age- and gender-wise, with sensitivities of 87.5% and 100%, and specificities of 52.2% - 88.9%, respectively.
Conclusion: Neck circumference is a valid and simple tool to detect overweight and obesity in schoolchildren. It is also an indicator of the central distribution of fat in children aged 6 to 16 years.

Keywords: Neck circumference, Body Mass Index, overweight, obesity, Waist circumference, Hip circumference

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Introduction

Obesity is abnormal or excessive fat accumulation in the adipose tissue to the extent that health may be impaired [1]. The worldwide prevalence of overweight is on the rise. WHO estimates it to have tripled from 4% in 1975 to over 18% in 2016 in children aged 5-19 years [2]. Obesity increased from 1% in 1975 to 6% in girls and 8% in boys by 2016. If post-2000 trends continue, global levels of child and adolescent obesity will surpass those for moderately and severely underweight youth in the same age group by 2022 [4]. Childhood obesity is associated with a higher chance of obesity, premature death, and disability in adulthood, apart from the cardio-respiratory, osteoarticular and psycho-social morbidities in childhood itself [5]. It is observed that overweight and obesity are linked to more deaths worldwide than underweight. Hence, it is crucial to detect these conditions quite early in life and adopt timely interventions. For this, we need reliable and easy tools for their detection that can be utilized by health workers.

Body Mass Index (BMI) (weight (kilogram) / height $(m)^2$) provides the most useful albeit crude measurement of obesity. For children, there are age-specific WHO BMI centile charts for both boys and girls. A BMI $\geq 85^{th}$ centile is overweight, and $\geq 95^{th}$ centile is obesity [6].

Individuals with obesity and overweight differ in the extent of fat deposited as well as the regional distribution of that fat. Those with abdominal fat distribution (android obesity) are at increased risk for metabolic complications when compared to those with gynoid fat distribution in whom fat is more evenly and peripherally distributed [7]. Abdominal fat mass can vary dramatically within a narrow range of total body fat or BMI. BMI does not give any idea on the distribution of excess fat accumulation [8]. We need other measurements like waist circumference, waist-hip ratio, etc., or imaging modalities to identify patients at increased risk of obesity-related illnesses.

Waist Circumference (WC) is an indicator of fat accumulation that also correlates with abdominal fat distribution and is associated with ill health [9]. Hip circumference (HC) provides additional valuable information regarding gluteofemoral muscle mass and bone structure [10]. In adults, waist-hip ratio (WHR) >1 in males and >0.85 in females and waist circumference (WC) ≥94 in males and ≥80 in females indicates obesity [6]. WC can be influenced by food intake and cultural and social issues can interfere with getting an optimal WC and HC measured, especially in older female children. Thus, there is a need for more acceptable and reliable indicators of obesity and overweight.

Neck circumference is a novel anthropometric measurement that appears to be significantly correlated with indices of adiposity and abdominal obesity and hence is an indicator of metabolic risk in obese children [11]. If so, it can be used as a simple and time-saving tool for obesity detection in large population-based studies in both children and adults. Also, the practical and cultural issues met with measuring waist and hip circumference, especially in female adolescents, can be circumvented.

The present study intended to measure the neck circumference of school children aged 6 to 16 years and assess its correlation with BMI as well as waist circumference, hip circumference, and waist-hip ratio. We also tried to determine the age- and sex-specific optimal cutoff points for neck circumference in identifying obesity and overweight, using WHO BMI centile charts.

Materials and methods

This school-based cross-sectional study was performed on children aged 6-16 years studying in the primary and secondary schools within one educational zone, randomly selected from the district of Alappuzha, Kerala, South India. A minimum sample size of 1767 was required, after considering a 20% dropout. The subjects were selected by multistage random sampling. A prior sanction was obtained from the institutional ethics committee, concerned government authority, and school authorities. Informed consent from parents and assent from older children were also sought. Children with chronic systemic illnesses, skeletal abnormalities, and goiter were excluded from our study.

Study variables were weight, height, BMI, neck circumference**,** waist circumference (WC)**,** hip circumference (HC), waist-hip ratio (WHR). Trained interns were recruited for getting the measurements. Repeat measurements and cross-checking were randomly performed daily to ensure minimum intra- and interobserver variability. When variability was more than 0.5 CMs, reinforcement of training in performing the measurements was done. Weight was measured using a digital weighing machine corrected to the nearest 0.1kg. Height was measured using a portable stadiometer following the standard technique and the observed value was corrected to the nearest centimeter. BMI was calculated as weight in Kg/height in metre^2.WC was measured with a non-stretchable measuring tape horizontally connecting the midpoints between the lower costal margin and anterior superior iliac spine in the midaxillary line on each [12,13]. HC was measured along the levels of the greater trochanter [14]. Neck circumference was measured horizontally midway along the neck, horizontally connecting the mid-cervical spine and a point just below the cricoid cartilage with the person standing and looking straight forward [15,16]. BMI charts of WHO were used as standards for comparison.

Study setting

All primary and secondary schools under the jurisdiction of the local self-government of Ambalappuzha, who consented to the study, were selected.

Statistical analysis

Data were entered in MS EXCEL and analyzed with the SPSS software. Continuous variables were expressed in terms of mean and deviation for each age, separately for both genders [17]. Discrete variables were presented as a percentage [18]. Spearman's rho correlation coefficient was used to find the correlation between neck circumference and other variables and a *P*-value of less than 0.05 was considered significant [19]. Kendell's coefficient of concordance was determined for BMI, NC, and WC. ROC analysis was employed to obtain the cutoff values for NC in each age group [20].

Results

A total of 1797 students aged 6 to 16 years were included in the study. Among them, 50.9% (914) were males and 49.1% (883) were females (Table 1).

Table 1: Age- and gender-wise distribution of the study population

Age (yrs)	Male	Female	Total (%)	Age yrs.	Male	Female	Total (%)
6	37	30	67 (3.7)	12	75	94	169 (9.4)
7	85	93	178 (9.9)	13	74	72	146 (8.1)
8	100	85	185 (10.3)	14	90	99	189 (10.5)
9	105	83	188 (10.5)	15	94	73	167 (9.3)
10	120	118	238 (13.2)	16	39	19	58 (3.2)
11	95	117	212 (11.8)	Total	914	883	1797(100)

All age groups had a relatively uniform representation except for the extreme ones. In the older children, this was due to concerns of parents regarding loss of study time if participating in the study and some cases, religious reasons, which prevented them from giving consent. In the 6-year age group, this was because of the small number of students in the schools as many of this group were still in anganwadi or preprimary schools. Both genders were almost equally represented with a slight preponderance of males (Table 2).

Table 2: Age- and gender-wise mean (with standard deviation) of various anthropometric indices

Age (yrs)	Male BMI (SD)	WC,CM (SD)	HC,CM (SD)	NC,CM (SD)	WHR (SD)	Female BMI (SD)	WC,CM (SD)	HC,CM (SD)	NC,CM (SD)	WHR (SD)
6	14.8 (2.7)	52.8 (7.1)	61.3 (6.4)	25.1 (1.8)	0.86 (0.05)	14.2 (1.7)	53.2 (4.8)	61.5 (4.9)	25 (1.2)	0.87 (0.05)
7	15.0 (2.5)	54.8 (7.0)	63.3 (6.4)	26.0 (2.1)	0.87 (0.05)	14.5 (2.2)	53.9 (7.2)	62.8 (5.6)	24.8 (1.6)	0.86 (0.07)
8	15.3 (2.7)	55.8 (7.2)	64.8 (7.1)	26.1 (2.0)	0.86 (0.04)	15.3 (2.5)	56.2 (6.6)	67.0 (6.1)	25.3 (1.6)	0.84 (0.05)
9	15.7 (2.8)	57.4 (7.8)	67.7 (7.1)	26.6 (2.1)	0.85 (0.05)	15.2 (2.8)	57.2 (7.2)	69.0 (6.8)	26.0 (1.9)	0.83 (0.06)
10	16.1 (3.1)	58.8 (8.3)	69.7 (7.6)	27.6 (2.0)	0.84 (0.05)	15.8 (3.1)	57.7 (7.4)	71.5 (8.0)	26.6 (1.9)	0.81 (0.04)
11	16.5 (3.7)	61.4 (10.2)	71.8 (8.7)	27.9 (2.4)	0.85 (0.06)	16.1 (3.0)	59.2 (6.7)	73.6 (7.2)	27.2 (1.7)	0.81 (0.05)
12	17.1 (3.4)	63.4 (10.2)	74.7 (8.6)	28.6 (2.0)	0.85 (0.06)	16.9 (3.7)	61.9 (7.2)	77.5 (8.2)	27.9 (2.0)	0.80 (0.05)
13	16.7 (3.3)	63.5 (9.9)	86.0 (8.0)	29.1 (2.1)	0.82 (0.10)	18.3 (3.5)	64.3 (8.6)	82.2 (8.4)	28.9 (2.1)	0.78 (0.05)
14	17.6 (3.5)	66.3 (10.4)	81.1 (9.1)	30.6 (2.3)	0.82 (0.06)	18.0 (2.8)	62.5 (8.3)	81.3 (6.5)	28.7 (1.5)	0.77 (0.07)
15	18.0 (2.7)	66.7 (8.1)	83.6 (7.0)	31.8 (2.0)	0.80 (0.06)	19.3 (2.9)	66.2 (7.1)	84.0 (5.9)	29.4 (1.6)	0.79 (0.05)
16	18.2 (2.8)	67 (8.2)	85.2 (6.9)	32.2 (1.9)	0.79 (0.05)	18.9 (2.8)	63.4 (6.6)	82.4 (6.3)	29.3 (2.0)	0.77 (0.05)

Various anthropometric measurements showed varying trends across different ages and genders. BMI consistently increased with age in males. The mean BMI varied from 14.8 (2.7) kg/m^2 in 6-year-old males to 18.2 (2.8) kg/m^2 among the 16-year-old males. Among females, the corresponding values were 14.2 (1.7) kg/m^2 and 18.9 (2.8) kg/m^2, respectively. A consistent increase in BMI was seen with age in females until 13 years of age. Until 12 years of age, boys had higher BMIs, and after that, girls dominated.

WC, HC, and NC increased with age. While no relation to gender was noted in the case of WC, the HC was consistently higher in females and the NC was higher in males in all age groups. WHR remained almost the same (0.85) until 12 years of age, and then came down to 0.80. In girls, it steadily fell from 0.87 at 6 years of age to 0.77 at 16 years of age. The prevalence of obesity and overweight were 3.3 % (59) and 6.6% (119), respectively in our study population. Both were higher among boys than girls (4.4% vs. 2.2% and 8% vs. 5.2%, respectively).

The correlation of NC with BMI and other indices such as BMI percentiles, WC, HC, and WHR, as determined by Spearman's rho correlation for various ages and genders, is given in Table 3.

Table 3: Correlation between NC and other indices

Age	Male BMI (+)	WC (+)	HC (+)	WHR +/ -	BMI Centile (+)	Female BMI (+)	WC (+)	HC (+)	WHR +/ -	BMI Centile (+)
6	0.8 *	0.8 *	0.9 *	-0.2 *	0.4 *	0.8 *	0.5 *	0.4 **	0.32 ***	0.4 **
7	0.7 *	0.7*	0.8 *	0.02 ***	0.7 *	0.7 *	0.7 *	0.7 *	0.2 ***	0.7 *
8	0.7 *	0.7 *	0.7 *	0.3 **	0.7 *	0.7 *	0.6 *	0.6 *	0.2 ***	0.7 *
9	0.7 *	0.7 *	0.7 *	0.3 **	0.7 *	0.6 *	0.6 *	0.7 *	0.2 ***	0.6 *
10	0.7 *	0.7 *	0.7 *	0.3 **	0.7 *	0.7 *	0.8 *	0.8 *	0.2 ***	0.7 *
11	0.8*	0.8 *	0.8 *	0.3 *	0.8 *	0.7 *	0.6 *	0.7 *	-0.1 ***	0.7 *
12	0.8 *	0.8 *	0.8 *	0.3 ***	0.8 *	0.8 *	0.8 *	0.8 *	0.1 **	0.8 *
13	0.8 *	0.7 *	0.8 *	0.2 ***	0.8 *	0.6 *	0.7 *	0.7 *	0.2 **	0.6 *
14	0.7 *	0.7 *	0.8 *	0.1 ***	0.7 *	0.6 *	0.6 *	0.6 *	0.2 **	0.6 *
15	0.6 *	0.5 *	0.5 *	0.2 ***	0.5 *	0.7 *	0.6 *	0.7 *	0.3 **	0.7 *
16	0.6 *	0.6 *	0.7 *	-0.2 ***	0.6 *	0.7 *	0.7 *	0.8 *	0.1 ***	0.7 **

* P<0.001, ** P<0.05, *** P>0.05

NC showed a significant, positive correlation with BMI and BMI centiles as well as with WC and HC in all age groups of males and females. This was not the case with WHR.

Regarding BMI, the correlation coefficient varied from +0.6 to +0.8 with a P-value of <0.001 among both boys and girls. A similar observation could be made for WC and HC except in 15-year-old boys. WHR was not significantly positively correlated with NC in any of the age groups of boys or girls.

Using ROC, the age- and gender-specific neck circumference cutoffs were determined for both overweight and obesity per the WHO centile charts. Table 4 shows these values along with the sensitivity and specificity rates. A sensitivity between 87.5% and 100% was noted in all groups, except in 7-year-old boys (for whom it was only 70%). The specificity varied from 52.2% to 88.9% (Table 4).

Table 4: Neck circumference cutoffs for overweight and obesity

Age	Male Overweight Cutoff (cm)	Sensitivity / Specificity (%)	Obesity Cut Off (Cm)	Sensitivity / Specificity (%)	Female Overweight Cut Off (cm)	Sensitivity / Specificity (%)	Obesity Cut Off (cm)	
6	25.3	100/68.7	25.8	100/76.5	24.9	100/64.3	25.6	100/79.3
7	26.1	70/72.9	26.8	60/73.8	25.3	100/79.3	25.8	100/83.1
8	26.3	88.9/76.7	27.3	100/85.3	25.8	80/76.3	26.3	100/82.7
9	27.3	87.5/76.1	27.8	80/77	26.3	100/75.6	27.3	100/86.3
10	27.8	92.9/67	28.8	100/76.1	26.8	10065.1	27.8	100/74.4
11	28.3	100/77.5	29.3	83.3/82	27.3	100/65.1	28.3	100/78.4
12	29.3	100/71.2	29.8	100/82.6	28.8	100/75.3	28.8	66.7/73.6
13	29.8	100/73.8	30.3	100/77.8	29.3	87.5/71.4	29.8	100/74.6
14	30.8	100/58.7	31.3	75/66.3	29.8	100/78.1	30.3	100/87.8
15	31.8	100/52.2	32.2	100/64.5	30.1	100/79.4	Not possible	
16	32.8	100/56.8	Not possible		31.3	100/88.9	Not possible	

Kendall's coefficient of concordance (w) was calculated as 0.996 for BMI and NC (P<0.001) and 0.998 for NC and WC (P<0.001). Statistically, there was a very good agreement between NC, BMI, and WC.

Discussion

Malnutrition is a universal public health problem in both children and adults globally, categorized as over- and under-nutrition. United Nations (UN) General Assembly proclaimed 2016–2025 the United Nations Decade of Action on Nutrition. This decade holds an unprecedented opportunity for addressing all forms of malnutrition. To further tackle the double and triple burdens of malnutrition, early screening, and identification of at-risk children, including those already with malnutrition, is essential.

BMI is the widely used anthropometric index to identify overweight and obesity. Apart from the difficulties in calculating it, BMI does not give any indication of the distribution or amount of fat in one's body. The amount of adipose tissue can vary considerably within a narrow range of BMI. Since the metabolic complications are directly related to upper body distribution of fat, we need better indicators of overall obesity and central obesity. Hydrostatic (underwater) weighing, air displacement plethysmography, imaging techniques like ultrasound, Dual-energy X-ray absorptiometry (DXA), near-infrared interactance are some of the more accurate methods for assessing total body fat and its distribution but cannot be used at population levels due to various reasons. For community-level screening, we need sensitive, reliable, easy, and acceptable screening tools. Neck circumference appears to be a promising one.

In our present study, a significant positive correlation was observed between neck circumference (NC) and BMI as well as waist circumference (WC) and hip circumference (HC) in schoolchildren aged 6 – 16 years of both genders. Age and gender-specific cut-off values could be obtained with a sensitivity of more than 80% in all the groups. No consistent correlation was noted between NC and WHR.

Nafiu et al. [20] studied 1102 children aged 6-18 years and found that NC was significantly correlated with indices of adiposity and can reliably identify children with high BMI. He could also determine NC cut-offs for obesity and overweight for different age groups and both genders. In their studies among Iranian schoolchildren, Taheril et al. [21], and on Indian children, Lipilekha et al. [22] made similar observations. Katz et al. [23] could provide age and sex standardized reference values of NC threshold for overweight and obesity for Canadian children [24]. Interestingly, Kim et al. [24] did not strongly support the use of NC measurement as a useful screening tool for classifying childhood overweight/obesity.

Hassan et al. [25] observed that NC is a reliable indicator of central obesity and it showed significantly positive correlations with BMI, WC, HC, and systolic and diastolic blood pressure, but not with dyslipidemia in children.

The cut-off values in our study differ from those of the above-mentioned studies indicating the need for establishing region-specific standards for better utilization of this screening tool.

Limitations

There is a fairly low representation of the ages of 6-16 years due to practical issues.

Recommendations

A single large cohort of children may be followed up over the years starting from their school entry to their leaving higher secondary school, to study the pattern of increase in NC. Thus, reference charts for NC for different ages could be prepared. Future research can be planned to assess the correlation of Neck Circumference with more objective measures of central obesity, such as ultrasound-guided visceral fat estimation.

Conclusions

Neck circumference is significantly correlated with measures of obesity, such as BMI, WC, and HC, and can be utilized as a screening tool for central obesity to detect children at high risk for metabolic complications of obesity and sleep apnea. Region-wise charts of NC for different ages and both genders should be made available.

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