Neck circumference measurement as a screening tool for obesity in children – A cross sectional study

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ARTICLE INFO

Keywords:

Children
Obesity
Body mass index
Neck circumference

ABSTRACT

Background: Conventional anthropometric measurements for obesity in children offer several limitations which the newer methods propose to overcome.

Objective: To determine whether neck circumference can be used as a screening tool to identify obesity in children and to find out the correlation between neck circumference and body mass index, waist circumference, waist/hip ratio in evaluation of obesity in children.

Methodology: This was a cross-sectional study. Total 360 children (13–16 years) of a private school were study participants. Body mass index, waist circumference, hip circumference, waist-to hip ratio was compared with neck circumference of the same subjects. Pearson's correlation coefficient was calculated between neck circumference and other obesity indices. Data was analyzed and compared using *t*-test/ANOVA and the significance level was set at $p < 0.05$.

Result: The mean weight, waist circumference, neck circumference, hip circumference was significantly less in the group with Body mass index less than 23 kg/m^2 in comparison to the subjects with Body mass index greater than or equal 23 kg/m^2 (p value < 0.0001) for both the sexes. Ratio of males was more than females and the mean $\pm$ Standard Deviation of Body mass index was $20.88 \pm 3.9 \text{ kg/m}^2$ with prevalence of obesity 25.56%.

Conclusion: The neck circumference is an efficacious tool for screening obesity with good sensitivity and specificity. There was a significant correlation between neck Circumference and different anthropometric measurement in both the sexes.

1. Introduction

Obesity and overweight can lead to a range of chronic non-communicable diseases, such as cardiovascular disease, metabolic syndrome, and diabetes mellitus etc.¹ Obesity in young age is a growing chief public health crisis, particularly hazardous for type 2 diabetes mellitus, hypertension, and cardiovascular disorders in the later stages of life. In children, the prevalence of obesity has increased up to 300% over the last 40 years.² The National Health and Nutrition Examination Survey (2009–2010) found 32% of children between 2 and 19 years of age to be overweight or obese.² Obesity varied from 10 to 40% in different European populations.³ Upper body trunk girth is an important predictor of obesity related complications such as hypertension, diabetes and cardiovascular diseases.²

Currently various methods have been used to assess obesity in children like BMI and waist hip ratio. But each of them has limitations. BMI

is widely used tool to define obesity in children as well as adults but is actually an inaccurate and misleading indicator as it is suboptimal to assess the total body fat and central obesity. Waist circumference is not only time consuming but also problematic in terms of cultural and environmental issues. Also, WC may be affected by abdominal distention after consuming meals.^{3,4} Thus, these are broad and non-specific tools. So, there is a need of alternative tools to assess obesity in children as prevention of childhood obesity can prevent non communicable diseases in adulthood.

Neck circumference (NC), an indicator of upper body subcutaneous adipose tissue allocation can predict a higher metabolic threat.^{1,2} Neck circumference is correlated with cardiovascular disease risk factors even after adjustment for visceral adipose tissue (VAT) and BMI. These findings indicate that upper body fat may be a distinctive, pathogenic fat store.⁵ Neck circumference measurement is a distinct anthropometric dimension compared to body mass index, waist circumference,

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<https://doi.org/10.1016/j.cegh.2020.100683>

Received 19 October 2020; Received in revised form 28 November 2020; Accepted 13 December 2020

Available online 20 December 2020

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waist/hip ratio and waist height ratio^{1,6} Significant advantage of the NC measurement in an assessment of overweight and obesity which is evaluated on a more secure body area when compared to WC. An added advantage of using NC as a proxy for upper body fat distribution is that it shows no variation in size throughout the day.^{1,10} The scientific literature on the accuracy of neck circumference (NC) as a tool to identify overweight and obesity is especially scarce, mainly in the children. Hence the present study aimed to determine the validity of neck circumference as a screening tool for obesity in children. The main objectives of the study were to determine whether neck circumference can be used as a screening tool to identify obesity in children and to find out the correlation between neck circumference and body mass index, waist circumference, waist/hip ratio in evaluation of obesity in children.

2. Materials and methods

The present Cross-sectional study was conducted in one of the private schools of Belagavi for 2 months on 360 children, studying in Class 8th to 10th in an urban school in Belagavi.

Universal sampling was carried out and all the students present on the data collection days were included in the study i.e., 360 students. School children aged between 13 and 16 years were included in the study while Children having goitre, cervical lymph adenopathy, neck masses, neck deformity, diabetes, Cushing's disease, and children on medication (steroid) were excluded. Data collector was trained in data collection and measurements.

Data was collected by the Principal investigator using weighing machine, height measuring scale and flexible measuring tape. Height was measured by using a stadiometer, each participant was instructed to stand barefoot and head held in Frankfurt horizontal plane to the nearest 0.1 cm. Weight was measured by using a calibrated electronic weighing scale, to the nearest 0.1 kg. Neck circumference was measured between the mid cervical spine and mid anterior neck, using a flexible measuring tape with the child in the standing position, head held erect and eyes facing forwards and neck in the horizontal plane at the level of most prominent position, the thyroid cartilage.

WC was measured by using flexible measuring tape to the nearest 0.1 cm with the child standing, and at the end of normal expiration at a point midway between the inferior margin of the lowest rib and the iliac crest.

Hip circumference was measured at the maximum circumference around the buttocks.

Waist-To-Hip Ratio (WHR) was calculated by dividing WC by HC.

BMI kg/m^2 was calculated and interpreted according to WHO guidelines using formula Weight in kilograms (kg)/(Height in meter). BMI for age and sex percentile growth curves were used to classify the subjects and was defined as Underweight (Less than 5th percentile), Normal weight (5th percentile to less than the 85th percentile), Overweight (85th to less than the 95th percentile) and Obese (Equal to or greater than the 95th percentile). Study subjects were divided into two categories based on BMI. One group with BMI less than 23 kg/m^2 and another group with BMI more than or equal to 23 kg/m^2 .

Informed consent was obtained from the head of the school and assent was obtained from school students. Informed consent was also taken from parents. Approval was obtained from the Institutional Ethics committee before instating the study.

2.1. Statistical analysis

Data was analyzed using R software version 3.6.1 and Excel. Categorical variables were represented in the form of frequency table. Continuous variables were represented as mean $\pm$ Standard Deviation (SD). Data was compared using *t*-test/ANOVA, Welch's *t*-test and Mann-Whitney test and the level of significance was set at $p < 0.05$.

3. Results

The present study recruited 360 participants between 13 and 16 years. Among the 360 subjects, 196 were males and the mean age observed was 14.38 ± 0.85 years and 164 were females. 92 subjects were identified with a BMI greater than 23 kg/m^2 . Prevalence of obesity was 25.56%.

Table 1 shows the distribution of age, neck circumference, waist circumference between the two groups and sexes. In males, mean weight, waist circumference, neck circumference, hip circumference was significantly less in the group with BMI less than 23 kg/m^2 compared to the subjects with BMI greater than or equal to 23 kg/m^2 (p -value < 0.05). In females, mean weight, height, waist circumference, neck circumference, hip circumference was significantly less in the group with BMI less than 23 kg/m^2 compared to the subjects with BMI greater than or equal to 23 kg/m^2 . All the anthropometric parameters were found to be significantly higher in overweight/obese children than their normal weight peers and higher in boys when compared to girls.

Table 2 illustrates the sensitivity, specificity, area under curve, cut-off values, positive and negative likelihood ratio for neck circumference, waist circumference and hip circumference among males and females. In males, area under the curve for neck circumference assessing obesity was 0.7356. A male patient was 4.05 times more likely to be obese if his neck circumference was greater than or equal to 32.5 cm (cut-off value). In females, area under the curve for neck circumference assessing obesity was 0.8178. A female subject was 6.07 times more likely to be obese if her neck circumference was more than or equal to 30.5 cm (cut-off value). Total prevalence of obese male and female subjects was 32.65% and 22.96% and 28.06% and 23.97% with respect to neck circumference and BMI, respectively.

Fig. 1 illustrates the Receiver Operating Characteristic (ROC) curve of neck circumference to screen obesity in males and females.

Table 3 presents the correlation between BMI and other variables over gender. In males, a strong positive correlation was present between neck circumference and age, weight, waist circumference, hip circumference and BMI by Pearson correlation test. By Spearman's correlation test, there was a small amount of positive correlation between neck circumference and age. In females, a strong positive correlation was present between neck circumference and weight, waist circumference, hip circumference and BMI by Pearson correlation test.

Table 4 presents the sensitivity and specificity analysis for neck circumference over age. In males, 100% sensitivity in age group of 16 years with the cut-off value for NC of 32.5 cm was reported. In females, 86% sensitivity was observed with the cut-off value for NC as 30.5 cm in the age group of 15 years.

Table 5 depicts a significant association between BMI and neck circumference for males by Chi-square test.

Table 1
Baseline characteristics of study participants.

Gender	Variables	BMI (kg/m^2)		p-value
		$<23 \text{ kg/m}^2$	$\geq 23 \text{ kg/m}^2$	
Male	Age	14.35 ± 0.8	14.5 ± 0.91	0.4931 ^M
	Weight (in kg)	50.59 ± 7.66	71.52 ± 12.74	<0.00001 ^{wt}
	Height (in cm)	163.73 ± 9.62	165.74 ± 9.48	0.2134 ^t
	Waist circumference	72.94 ± 6.97	90.02 ± 9.06	<0.00001 ^{wt}
	Neck circumference	31.09 ± 2.51	34.07 ± 1.99	<0.00001 ^t
	Hip circumference	85.59 ± 6.27	101.76 ± 8.01	<0.00001 ^t
Female	Age	14.34 ± 0.84	14.4 ± 0.89	0.9571 ^M
	Height (in cm)	156.95 ± 6.01	159.15 ± 5.76	0.01629 ^t
	Weight (in cm)	47.45 ± 6.25	66.42 ± 8.84	<0.00001 ^{wt}
	Waist circumference	68.9 ± 6.16	82.33 ± 8.14	<0.00001 ^t
	Neck circumference	29.51 ± 5.04	31.67 ± 1.97	0.002313 ^t
	Hip circumference	86.72 ± 5.44	100.42 ± 7.1	<0.00001 ^t

Abbreviations: t: *t*-test, Wt: Welch's *t*-test, M: Mann-Whitney test. *Significant p -value < 0.05 .

Table 2

Sensitivity and specificity analysis for neck, hip, and waist circumference over gender.

Gender	Variables	Sensitivity (CI)	Specificity (CI)	AUC (CI)	Cut-off	LR ⁺ (CI)	LR ⁻ (CI)
Male	Neck Circumference	78% (63%–89%)	81% (74%–87%)	0.7356 (0.6701–0.8011)	32.5 cm	4.05 (2.82–5.82)	0.28 (0.16–0.48)
	Waist Circumference	82% (68%–92%)	91% (86%–95%)	0.8426 (0.7785–0.9067)	81.5 cm	9.55 (5.58–16.34)	0.19 (0.10–0.37)
	Hip Circumference	87% (73%–95%)	89% (83%–94%)	0.8333 (0.7704–0.8961)	93.5 cm	8.18 (5.07–13.18)	0.15 (0.07–0.31)
Female	Neck Circumference	83% (69%–92%)	86% (79%–92%)	0.8178 (0.7525–0.8832)	30.5 cm	6.07 (3.78–9.74)	0.20 (0.10–0.37)
	Waist Circumference	89% (77%–96%)	83% (75%–89%)	0.8142 (0.7519–0.8765)	74.5 cm	5.23 (3.47–7.89)	0.13 (0.06–0.30)
	Hip Circumference	94% (82%–99%)	88% (81%–93%)	0.8652 (0.7519–0.8765)	92.5 cm	7.82 (4.76–12.86)	0.07 (0.02–0.22)

Abbreviations: AUC: Area Under Curve; LR⁺: Positive likelihood ratio; LR⁻: Negative likelihood ratio; CI: Confidence interval. **Fig. 1.** ROC Curve for males and females to screen the obesity.**Table 3**

Correlation analysis between neck circumference and other variables over gender.

Gender	Variables	Correlation coefficient	p-value
Male	Age	0.396941 (Spearman's rho)	<0.0001
	Weight (in kg)	0.8271033	<0.0001
	Waist circumference	0.7213742	<0.0001
	Hip circumference	0.8161293	<0.0001
	BMI (kg/m ²)	0.6775628	<0.0001
Female	Age	0.072409 (Spearman's rho)	0.3568
	Weight (in kg)	0.742741	<0.0001
	Waist circumference	0.67800	<0.0001
	Hip circumference	0.676661	<0.0001
	BMI (kg/m ²)	0.662298	<0.0001

*Significant p-value < 0.05.

Table 4

Sensitivity and specificity analysis for neck circumference over age.

Gender	Age (in years)	Neck circumference (Mean $\pm$ SD) kg/m ²	Sensitivity (CI)	Specificity (CI)	AUC (CI)	Cut-off (cm)
Males	13	30.07 $\pm$ 2.02	67% (22%–96%)	95% (77%–100%)	0.8565 (0.6519–1)	31.5
	14	31.57 $\pm$ 3.24	76% (50%–93%)	83% (71%–91%)	0.7357 (0.6286–0.8429)	32.5
	15	32.42 $\pm$ 2.09	80% (52%–96%)	71% (58%–83%)	0.6794 (0.5784–0.7804)	32.5
	16	32.93 $\pm$ 1.53	100% (54%–100%)	78% (40%–97%)	0.875 (0.7146–1)	32.5
Females	13	29.07 $\pm$ 2.07	71% (29%–96%)	91% (71%–99%)	0.8117 (0.6208–1)	30.5
	14	31.24 $\pm$ 6.94	85% (62%–97%)	76% (60%–89%)	0.78 (0.6736–0.8865)	30.5
	15	29.45 $\pm$ 1.76	86% (57%–98%)	92% (81%–98%)	0.855 (0.7421–0.9679)	30.5
	16	31.27 $\pm$ 2.2	83% (36%–100%)	80% (28%–99%)	0.8167 (0.5615–1)	30.5

Abbreviations: AUC: Area Under Curve; CI: Confidence interval.

4. Discussion

Before the 20th century, obesity was rare; but in 1997 World Health Organization (WHO) officially acknowledged obesity as a global epidemic.⁷ According to the WHO report, 65% of the world's population

Table 5

Comparison of neck circumference and BMI over gender.

		Male		Female	
		NC < 37	NC $\geq$ 37	NC < 37	NC $\geq$ 37
BMI (kg/m ²)	< 23	149 (99.33)	1 (0.67)	115 (99.14)	1 (0.86)
	$\geq$ 23	41 (89.13)	5 (10.87)	47 (97.92)	1 (2.08)
p-value		0.00199 ^{MC*}		1 ^{MC}	

MC: Monte-Carlo's simulation was used to obtain p-value; BMI: Body mass index, NC: neck circumference, *: Significant p-value < 0.05.

live in countries where overweight and obesity kill more people than underweight.⁸

The prevalence of obesity is growing at an alarming speed, and the harmful implications are renowned. The Waist hip ratio which is commonly used is usually known to recognize individuals with central obesity and overweight/obesity.⁶ But the limitation is waist circumference is less specific and can vary throughout the day in the postprandial period, in menstrual period, and according to bowel function.⁹

Neck circumference reflects the deposits of adipose tissue in the neck, which can be used as an indicator of subcutaneous adipose tissue in the upper body. The neck is at the junction between the head and the trunk, and is often not covered by clothing, which provides easy access for measurement.⁹ Similarly, NC measurements are less invasive than measuring WC and less cumbersome than assessing BMI.⁸

In present study, the observed ratio of males was more than females. The mean $\pm$ Standard Deviation of BMI was $20.88 \pm 3.9 \text{ kg/m}^2$, and prevalence of obesity was 25.56%.

A study conducted by Ferretti R de L et al. in children between adolescents showed that there was a significant correlation between neck circumference and body mass index in both the genders, ($31.62 \pm 4.54 \text{ kg/m}^2$, $p < 0.001$).¹⁰ Similar findings were observed by Yashoda et al. (2017), ($25.27 \pm 2.0 \text{ kg/m}^2$, ($p < 0.001$)), Rajagopalan et al. (2017), ($18.81 \pm 0.2 \text{ kg/m}^2$, $p < 0.001$) Kelishadi et al. (2016), ($31.35 \pm 0.7 \text{ kg/m}^2$, $p < 0.01$).^{2,11,12} Earlier Atef et al. (2015) ($28.98 \pm 1.6 \text{ kg/m}^2$, $p < 0.01$), Hassan et al. (2015), ($32.90 \pm 1.6 \text{ kg/m}^2$, $p < 0.01$), Kim et al. (2014), ($r = 0.78$, $p < 0.001$), Hatipoglu et al. (2010), ($28.0 \pm 0 \text{ kg/m}^2$, $p < 0.01$), also showed a similar outcome in various age groups between 6 and 18 years.^{11–16}

Numerous studies have reported the use of NC as a screening tool for the identification of obesity (high BMI), but the studies done in school children are limited. In the present study, mean weight, WC, NC, HC in males were observed significantly less in the group having less BMI than 23 kg/m^2 and in females, it was seen to have high or equal BMI after comparison. After comparison between the genders, females were 6.07 times more likely to be obese with NC of more or equal to 30.5 cm. Finally, it was observed that AUC was more for WC, HC when compared to NC in boys and girl's ratio. In males, 100% sensitivity in age group of 16 years with the cut-off value for NC of 32.5 cm and in females, 86% sensitivity was observed with the cut-off value for NC as 30.5 cm in the age group of 15 years was reported. Thus, the study confirmed the utility of NC to assess obesity among the children.

The study had some limitations, that is it was a cross-sectional study with a small sample size in a single geographic area. Although neck circumference had a strong correlation with various obesity parameters there is a need to derive and validate neck circumference cut-off values for different pubertal stages, different BMI categories and different age groups for the Indian population.

4.1. What is already known?

Currently various methods have been used to assess obesity in children like BMI and waist hip ratio. But each of them has limitations.

4.2. What this study adds?

The present study concluded that NC is a valuable tool for screening the obesity among children (13yrs–16yrs) with reasonable sensitivity and specificity. It also established the obesity predictor cut-off values for this populace. There was a strong positive correlation between neck circumference and weight, BMI, hip circumference, waist circumference in both the genders.

Funding

None.

Declaration of competing interest

None declared.

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