Neck Circumference as an Additional Tool for Detecting Children with High Body Mass Index

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Abstract: Background: Children overweight/obesity is an important risk factor for many health problems and an indicator of heart problems and diabetes mellitus later in life. There are numerous methods of assessing overweight and obesity. Children overweight is most commonly described by using BMI which does not adequately describe regional (central) adiposity, other indices of body fatness are being explored. The possible role of NC in screening for high BMI in children is not well characterized. The aims of this study were to examine the correlation between BMI and NC in children and to determine the best NC cutoff that identifies children with high BMI. **Methods:** Cross sectional study included 2762 preparatory school children, trained research assistants collected clinical data and anthropometric measurements from all children. Pearson correlation coefficients were calculated between NC and other obesity indices, then receiver operating characteristic analyses were done to determine the optimal NC cutoff for identifying children with high BMI. **Results:** among 2762, overweight and obesity were 15.1%. NC was significantly correlated with age, BMI, and waist circumference in both boys and girls. Optimal NC cutoff indicative of high BMI in boys ranged from 29.3 to 31.7 cm, while corresponding values in girls ranged from 28.6 to 30.8 cm. NC was a good indicator for BMI and even as good as WC. **Conclusions:** NC is significantly correlated with overweight/obesity and can reliably identify children with high BMI. NC is a simple technique that has good inter-rater reliability and could be used to screen for overweight and obesity in children.

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1. Introduction

Childhood overweight and obesity is a worldwide public health issue.[1,2] The most widely used tool for defining overweight and obesity in both adults and children is BMI, which is defined as an individual's weight in kilograms divided by the square of their height in meters (BMI=kg/m^2).[3] Despite the ease of use and popularity of BMI as an anthropometric tool, it is becoming increasingly clear that it is not a good proxy for regional adiposity.[4] Regional deposition of fat, especially in the upper body segment, is a better predictor of some obesity-related complications, such as hypertension, diabetes, and heart disease.[5] Many studies have demonstrated the value of waist circumference (WC) as an index of central obesity.[6,7] Other investigators have shown that WC, either singly or in combination with BMI, may have a stronger relation to some health outcomes than BMI alone.[8,9]

Neck circumference (NC) has also been used as a potential proxy for obesity and cardiovascular disease in adults.[10,11] Pediatric investigators[12-14] have attempted to use NC to screen for overweight and obesity in children. Also, they used NC as a parameter to determine metabolic risk factors in obese children[15], as an additional measure that might expand the ability of BMI for the identification of prehypertension in normal weight children and adolescents[16], and as a screening tool of cardiovascular risk in children.[17]

The objectives of this study were to examine the correlation between NC and BMI in children, to examine the ability of NC to identify correctly children with high BMI, and to determine the best NC cut point for identifying children of various ages as overweight/obese. Our a priori hypothesis was that a significant proportion of children with high BMI would also have big NC.

2. Methods

After institutional approval, 2762 children, aged 12 to 15 years, were recruited to the study from randomly selected four preparatory schools at Ismailia governorate: two urban and two rural schools (for boys and girls). Children with goiter or other neck masses, and neck deformity, were excluded from this study.

Measurements: Two trained research assistants took all clinical and anthropometric measurements. Their measurements were standardized to minimized intra-rater and inter-rater errors.

Height was measured to the nearest 0.1 cm by using a wall mounted height scale with the children shoeless and head held in Frankfurt horizontal plane. Body weight was measured, to the nearest 0.1 kg, by using a calibrated digital weighing scale with children using light closes and shoeless. Neck Circumference (NC) was measured by using a flexible tape, with the children in the standing position, head held erect, at the level of the thyroid cartilage. Waist Circumference (WC) was measured (to the nearest 0.1 cm) with the children standing, at the end of normal expiration, by using an inelastic tape at a point midway between the inferior margin of the lowest rib and the upper point of the iliac crest. Measurements were obtained with the tape snug but not compressing the skin. BMI was calculated for all children and was converted to age- and gender-specific percentiles according to the 2000 Centers for Disease Control and Prevention growth curves.[18]

BMI was calculated for each child and percentiles were recorded according to the age and gender specific growth chart of Egyptian children.[19] Children with a BMI <85th percentile were classified as having normal weight, whereas children with a BMI >85th percentile were classified as being overweight/obese.[18] These data were grouped according to age and gender.

Statistical Analysis: data analysis was conducted using SPSS 17 statistical package for Windows. Means and Standard Deviations were calculated for height, weight, BMI, NC and WC, and were compared for each age and gender. Pearson correlation coefficient was used to explore the association between NC and other continuous variables, such as age, WC, and BMI.

Receiver Operating Characteristic (ROC) analyses[20] were used to determine the predictive validity of NC as well as evaluate optimal cutoff values for identifying overweight or obese children. ROC curves determine the discriminatory power of a screening measure for correctly identifying individuals on the basis of their classification by a reference test. The ROC curve is a plot of true-positive rate (sensitivity) against the false-positive rate (1-specificity). A good test will have its ROC curve skewed to the upper left corner.[21] The area under the curve (AUC) describes the probability that a test will correctly identify a pair of children who do and do not have a disease and were randomly selected from a population; a perfect score will have an AUC of 1, whereas an AUC of 0.5 means that the test performs no better than chance. For this study, children with true-positive results were those with high BMI and Big NC, children with false-positive results were those with high NC and low BMI, and children with false-negative results were those with low NC and high BMI. Sensitivity was calculated as true-positive results/ (true-positive results + false-negative results); specificity was calculated as true-negative results/(true-negative results + false-positive results). Cutoff values and the corresponding AUC as well as the likelihood ratios (positive [LR +] and negative [LR -]) for NC that were predictive of overweight/obesity were computed for each age and gender. The LR+ (+vePV) of a positive test result is sensitivity divided by 1-specificity and indicates how much the odds of a disease increase when a test is positive. Conversely, the LR- (-vePV) indicates 1-sensitivity divided by specificity and indicates how much the odds of a disease decrease when a test is negative.[22]

3. Results

A total of 2762 preparatory school children (12-15 years age), both sexes were recruited to this study. Tables 1 presents the baseline characteristics of the studied children, including the mean height, mean weight, NC, WC and their SD for each age (12, 13, 14 and 15 years) and gender. Number of overweight/obese children was 416 (15.1%) of the studied sample. Distribution of children according to body weight (normal and overweight/obese), age, gender, and 85th percentile was presented in table 2.

Table 3 compares means and SD of children's age, weight, height, BMI, WC and NC in high and normal BMI for both sexes. Except for age, all means for boys and girls were significantly higher in overweight/obese children than in their normal weight peers.

Table 4 presents the Pearson's correlation coefficients between NC (cm) and some clinical and anthropometric parameters for boys and girls. NC showed a strong positive correlation with age, BMI, WC, and height and weight in both boys and girls.

Table 5 shows the correlation coefficients for NC and BMI, together with the AUC for each age group and gender, including the optimal NC cutoffs and the corresponding sensitivities and specificities for classifying children into high BMI groups. The predictive values for each cutoff points are also shown. For example, +vePV for a 12-year-old boy with NC 29.3 cm indicates that he is 2.09 times more likely to be overweight or obese than a 12-year-old boy with NC values below this cut point.

As in table 5, table 6 shows the Pearson's correlation coefficient for WC and BMI, together with the AUC for each age group and gender, including the optimal NC cutoffs and the corresponding sensitivities and specificities for classifying children into high BMI groups. The predictive values for each cutoff points are also shown.

Tables 5 & 6 demonstrate that NC has performed comparably as good as WC in predicting high BMI and so overweight and obesity in the studied children.

Table (1): Baseline characteristics of children participated in the study classified according to age and gender

Gender/age	No. (%)	Ht Mean ±SD	Wt Mean ±SD	NC ±SD	WC ±SD
BOYS age (yrs)	(n=1327)				
12	244 (18.4)	152.0±8.1	43.5±9.8	27.3±2.7	70.5±7.7
13	393 (29.6)	156.8±5.6	52.9±11.9	29.1±3.0	73.9±11.4
14	377 (28.4)	160.4±6.3	56.9±12.0	30.0±2.7	75.2±9.7
15	313 (23.6)	165.2±5.2	58.0±10.3	30.3±2.3	76.2±8.5
GIRLS age (yrs)	(n=1435)				
12	295 (20.6)	150.8±6.0	49.6±11.6	27.2±2.9	71.5±7.9
13	407 (28.4)	153.3±5.6	55.9±13.3	29.4±3.2	73.4±10.6
14	389 (27.0)	157.1±5.2	60.9±13.1	30.1±2.9	76.5±9.9
15	344 (24.0)	157.6±6.1	60.8±6.2	30.8±3.0	77.2±6.5

Table (2): Distribution of overweight/obese and normal weight children according to age groups and gender

Gender/age	BMI Mean ±SD	85th Percentile	Overweight /Obese No. (%)	Normal Weight No. (%)
BOYS age (yrs)			(n=193)	(n=1134)
12	18.7±3.1	21.0	35 (14.3%)	209 (85.7%)
13	21.4±4.2	24.2	58 (14.8%)	335 (85.2%)
14	22.0±3.8	25.0	55 (14.6%)	322 (85.4%)
15	21.2±3.6	23.6	45 (14.4%)	268 (85.6%)
GIRLS age (yrs)			(n=223)	(n=1211)
12	21.7±4.2	25.8	46 (15.6%)	248 (84.4%)
13	23.6±4.7	29.1	61 (15.0%)	346 (85.0%)
14	24.5±4.6	29.0	62 (15.9%)	327 (84.1%)
15	24.3±3.9	26.6	54 (15.7%)	290 (84.3%)
Total			416 (15.1%)	2346 (84.9%)

Table (3): Mean values ±SD of children's characteristics according to BMI and gender

Variables	Normal BMI (n=415)	High BMI (n=2346)	*P value*
Boys			
Age (yrs)	13.6±1.0	13.6±1.0	.9
Weight (kg)	73.4±12.3	50.1±8.5	<.001
Height (cm)	161.7±7.4	158.5±7.6	<.001
BMI (kg/m^2)	28.1±4.5	19.8±2.2	<.001
WC (cm)	88.6±8.0	71.5±7.9	<.001
NC (cm)	33.4±2.2	28.5±2.4	<.001
Girls			
Age (yrs)	13.5±1.0	13.5±1.0	.9
Weight (kg)	77.7±10.7	53.4±9.6	<.001
Height (cm)	156.7±5.9	154.5±6.3	<.001
BMI (kg/m^2)	31.5±3.2	22.2±3.0	<.001
WC (cm)	86.5±6.1	72.5±7.9	<.001
NC (cm)	33.1±3.2	28.8±2.8	<.001

Table (4): Relationship between NC and other anthropometric variables by gender

Variables	NC (cm)			
	Boys		**Girls**	
	r	*P*	*R*	*P*
Age	.33	<.001	.36	<.001
Weight	.68	<.001	.68	<.001
Height	.34	<.001	.39	<.001
BMI	.67	<.001	.65	<.001
WC (cm)	.72	<.001	.63	<.001

Table (5): Pearson's correlation coefficient, AUCs, p value, 95%CI, cutoff values, sensitivity and 1-specificity for NC associated with overweight/obesity among the study group of children

	Pearson's coefficient NC/BMI	AUC	P value	95% CI	Cutoff Point	Sensitivity	1-Specificity	+vePV (LR+)	-vePV (LR-)
BOYS									
12	.619	.898	<.001	.83-.96	29.3	.94	.45	2.09	0.10
13	.735	.938	<.001	.91-.96	31.3	.91	.16	5.69	0.10
14	.633	.947	<.001	.92-.97	32.3	.91	.09	10.11	0.10
15	.563	.943	<.001	.91-.97	31.7	.96	.16	6.00	0.05
GIRLS									
12	.728	.912	<.001	.88-.94	28.6	.96	.17	5.65	0.05
13	.628	.881	<.001	.85-.92	29.5	.95	.31	3.06	0.07
14	.576	.811	<.001	.76-.86	29.7	.90	.44	2.05	0.18
15	.640	.880	<.001	.83-.93	30.8	.91	.37	2.46	0.14

Table (6): Pearson's correlation coefficient, AUCs, p value, 95%CI, cutoff values, sensitivity and 1-specificity for WC as a predictor of overweight/obesity among the study group of children

	Pearson's coefficient WC/BMI	AUC	P value	95% CI	Cutoff Point	Sensitivity	1-Specificity	+vePV (LR+)	-vePV (LR-)
BOYS									
12	.659	.862	<.001	.78-.95	65.8	.97	.77	1.26	0.13
13	.732	.932	<.001	.91-.96	79.0	.95	.18	5.28	0.06
14	.711	.972	<.001	.96-.99	83.5	.93	.09	10.30	0.08
15	.555	.968	<.001	.94-.99	84.5	.91	.03	30.30	0.09
GIRLS									
12	.793	.912	<.001	.88 -.94	77.5	.91	.17	5.35	0.11
13	.824	.940	<.001	.92-.96	80.5	.93	.19	4.90	0.09
14	.825	.934	<.001	.91-.96	83.3	.90	.17	5.29	0.12
15	.717	.885	<.001	.84-.93	77.5	.98	.46	2.13	0.04

4. Discussion

Obesity is one the most serious chronic health problem facing children in many parts of the world and has been described as a potential cause for the decline in life expectancy during the 21st century.[23] Many studies have linked increased adverse health outcomes with BMI >85th percentiles.[18,24] To control the childhood obesity epidemic, we need to have available monitoring tools that are relatively cheap, quick and easy to use, and generally acceptable to both clients and health practitioners. Various methods are available for assessing overweight in adults and children. Some techniques such as height, weight, waist circumference (WC), and hip girths and computations waist-to-hip ratio and Body Mass Index (BMI) are applicable in physician clinics or primary health care facilities. In the current study, NC and WC were highly correlated with BMI in different age and gender groups. NC was a good parameter for BMI and even as good as WC. WC has been shown to be especially useful as an index of central adiposity and performs better than BMI in predicting abnormal cardiometabolic phenotyp*es*[25]; however, WC measurement may be time-consuming and culturally or environmentally problematic, especially in the winter months because clothes have to be removed for its accurate measurement. In addition, WC may be affected by postprandial abdominal distension. Several adult studies have documented the value of NC as a simple screening tool for identifying individuals with high BMI.[11,22,26] Pediatric investigators have explored the potential value of NC measurement as an index of high BMI.[12,14,26] Consistent with previous findings in Turkish children,[12] the results of this investigation showed that NC performed well as an index of high BMI in the children of both genders; therefore, NC could be a useful screening instrument for identifying overweight or obese children as well as children who are at risk for central fat distribution which is an important predictor of poor cardiovascular health. NC measurement is inexpensive, is easier to obtain than other markers of adiposity (WC and BMI), and has good inter-rater reliability. In addition, NC measurement may be predictive of obstructive sleep apnea, especially in obese children.

Conclusions

NC properly identified a high proportion of children who were overweight or obese. NC is a simple technique that has good inter-rater reliability and could be used to screen for overweight and obesity in children. Our NC cutoffs, which correctly identified the majority of children with high BMI, could be used as a reference for boys and girls who are aged 12 to 15 years. Additional studies to evaluate the usefulness of NC as an index of adiposity in younger children are warranted.

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References:

1.Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003–2006. JAMA. 2008; 299(20): 2401–2405
2.Obesity: preventing and managing the global epidemic – report of a WHO consultation. World Health Organization. Tech Report Series. 2000;894:i-xii, 1-253.
3.Obesity: preventing and managing the global epidemic—report of a WHO consultation. World Health Organ Tech Rep Ser.2000;894:i–xii, 1–253
4.Walton C, Lees B, Crook D, Worthington M, Gods and IF, Stevenson JC. Body fat distribution rather than overall adiposity influences serum lipids and lipoproteins in healthy men independently of age. Am J Med. 1995;99(5):459–464
5.Kissebah AH, Krakower GR. Regional adiposity and morbidity. Physiol Rev. 1994;74(4): 761–811
6.Despre´ s J-P, Lemieux I, Prud'homme D. Treatment of obesity: need to focus on high risk abdominally obese patients. BMJ. 2001; 322(7288):716–720
7.Bigaard J, Tjonneland A, Thomsen BL, Overvad K, Heitmann BL, Sorensen TI. Waist circumference, BMI, smoking, and mortality in middle-aged men and women. Obes Res. 2003;11(7):895–903
8.Janssen I, Katzmarzyk PT, Ross R. Waist circumference and not body mass index explains obesity-related health risk. Am J Clin Nutr. 2004;79(3):379–384
9.Bigaard J, Frederiksen K, Tjønneland A, *et al.* Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. Int J Obes (Lond). 2005;29(7):778–784
10.Ben-Noun L, Laor A. Relationship of neck circumference to cardiovascular risk factors. Obes Res. 2003;11(2):226–231
11.Ben-Noun L, Sohar E, Laor A. Neck circumference as a simple screening measure for identifying overweight and obese patients. Obes Res. 2001;9(8):470–477
12.Hatipoglu N, Mazicioglu MM, Kurtoglu S, Kendirci M. Neck circumference: an additional tool of screening overweight and obesity in childhood. Eur J Pediatr. 2010;169(6): 733–739
13.Mazicioglu MM, Kurtoglu S, Ozturk A, Hatipoglu N, Cicek B, Ustunbas HB. Percentiles and mean values for neck circumference in Turkish children aged 6-18 years. Acta Paediatr. 2010;99(12):1847-53
14.Lou DH, Yin FZ, Wang R, Ma CM, Liu XL, Lu Q. Neck circumference is an accurate and simple index for evaluating overweight and obesity in Han children. Ann Hum Biol. 2012;39(2):161-5
15.Kurtoglu S, Hatipoglu N, Mazicioglu MM, Kondolot M. Neck circumference as a novel parameter to determine metabolic risk factors in obese children. Eur J Clin Invest. 2012 ;42(6):623-30
16.Guo X, Li Y, Sun G, Yang Y, Zheng L, Zhang X, Sun Z, Ma H, Wang N, Jiang M, Li J, Sun Y. Prehypertension in children and adolescents: association with body weight and neck circumference. Intern Med. 2012;51(1):23-7
17.Androutsos O, Grammatikaki E, Moschonis G, Roma-Giannikou E, Chrousos GP, Manios Y, Kanaka-Gantenbein C. Neck circumference: a useful screening tool of cardiovascular risk in children. Pediatr Obes. 2012;7(3):187-95
18.Kuczmarski RJ, Ogden CL, Guo SS, *et al.*, 2000 CDC growth charts for the United States: methods and development. Vital Health Stat 11. 2002; (246):1–190.
19.Egyptian national research: Tracking of body mass index in children in relation to overweight in adulthood. Am J Clin Nutr. 2002; 70 (suppl): 145S –148S.
20.Van der Schouw YT, Verbeek AL, Ruijs JH. ROC curves for the initial assessment of new diagnostic tests. Fam Pract. 1992; 9(4):506–511
21.Zhou X-H, Obuchowski NA, McClish DK. Statistical Methods in Diagnostic Medicine. New York, NY: Wiley-Interscience; 2002
22.Olubukola O. Nafiu, Constance Burke, Joyce Lee, Terri Voepel-Lewis, Shobha: Malviya and Kevin K. Tremper : Neck Circumference as a Screening Measure for Identifying Children With High Body Mass Index. Pediatrics 2010;126; e306-310.
23.Olshansky SJ, Passaro DJ, Hershow RC, *et al.* A potential decline in life expectancy in the United States in the 21st century. N Engl J Med. 2005;352(11):1138–1145.
24.Field AE, Cook NR, Gillman MW. Weight status in childhood as a predictor of becoming overweight or hypertensive in early adulthood. Obes Res. 2005;13(1):163–169.
25.Bitsori M, Linardakis M, Tabakaki M, Kafatos A. Waist circumference as a screening tool for the identification of adolescents with the metabolic syndrome phenotype. Int J Pediatr Obes. 2009; 4(4):325–331.
26.LaBerge RC, Vaccani JP, Gow RM, Gaboury I, Hoey L, Katz SL. Inter- and intra-rater reliability of neck circumference measurements in children. Pediatr Pulmonol. 2009;44(1):64–69.

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