ORIGINAL RESEARCH ARTICLE

Neck Circumference as A Screening Tool for Obesity in Pre- and Primary School Children in Puducherry India – A Cross-Sectional Study

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ABSTRACT

Introduction: Obesity has become the 21st Century's greatest challenge and threat. Around 50% of the obese children become obese adolescents, of which 80% become obese adults.

Methodology: Cross-sectional analytical study was done on 930 pre- and primary school children. Neck circumference, weight, height, waist and hip circumference was recorded. Overweight/obese identified according to WHO standards. Age-specific percentile charts for boys and girls were drawn with data from the apparently normal children in the study population.

Results: The Neck Circumference measurements ranged from 23.64(±1.16) to 28.49(±2.87) in boys and 23.59(±1.63) to 27.6(±2.67) in girls. ROC analysis derived cut-offs for overweight and obesity in each age group/gender were found to have high sensitivity (80-100%) and specificity (60-95.9%). Using the reference percentile data/curves, and the cut –offs obtained by ROC analysis, a neck circumference above the 75th percentile for age and gender can be regarded as overweight and above the 90th percentile as obese in both boys and girls.

Conclusion: The study concludes that the Neck circumference is a valid and effective screening tool for overweight/obesity in pre and primary school children.

Keywords: Anthropometry, Childhood obesity, South India

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INTRODUCTION

Obesity has become the 21st Century's greatest challenge and threat.[1] Around 50% of the obese children become obese adolescents, of which 80% become obese adults.[2,3] Asian children, though with a comparatively less prevalence is also showing elevating trends. India shows a prevalence range of 3% to 29%[4,5] justifying why this condition is becoming such a global issue.

Evaluation of overweight/obesity in clinical practice is mainly by anthropometric measurements like Body mass index (BMI), Waist circumference (WC).[6] BMI has a limitation that it lacks adequate information of body fat distribution i.e. lean mass and fat mass. It has high specificity but low sensitivity.[7] WC and waist-hip ratio have been found to correlate with abdominal obesity, however, its utility in the community setting (obtaining accurate measurements in a proper setting) is cumbersome. The need for an anthropometric indicator that is simple, bedside, non-invasive, cost-effective, feasible to all ages and applicable in the community setting was warranted.

Neck circumference (NC) measurement is identified as a relatively new and time-saving anthropometric tool used to evaluate overweight and obesity. It gives a measure of the upper body adiposity, which has a steady increase throughout childhood and adolescence, is also an important factor for assessing cardio metabolic risks.[8] Studies on the NC as a measure of obesity in pre and primary school children till adolescents have been reported from different parts of the world[9] including studies on adolescents in India[10-12]. However, reports on pre-and primary school children from our country are limited.[13]

Puducherry encompasses a heterogeneous population. Studies on the prevalence of obesity in school going and adolescent children in Puducherry assessed by the standard methods have been reported[6,14] however, NC as an anthropometric tool is yet to be validated. This study would also be the primary study using NC as a parameter in pre-and primary school children in Puducherry.

The study was conducted to establish age-specific cut-off reference values for Neck Circumference measurements in children aged 3-11years from Puducherry and its utility in assessing overweight/ obesity.

METHODOLOGY

This was a cross-sectional analytical study. Five Government and five private co-education schools (Pre and Primary) were selected through the lottery method, from in and around Puducherry. Study duration was 18 months (November 2021 to July 2023). A sample size of 929 was fixed based on a previous study [10] taking into account 68% specificity with 95% confidence interval and 3% precision. The final data collected was from 930 students. All healthy children from the age of 3-11 years who had voluntarily filled up consent/assent form and questionnaire were included. Children with physical limitations, mental disability, undergoing any form of therapy for acute/chronic illnesses, exogenous steroid intake were excluded. Children with conditions that are likely to interfere with the NC such as goitre, cysts or swellings in the neck, or abnormalities of the cervical spine were also excluded. From selected schools, those with total strength less than 100, all the children present and segregated from the exclusion category were taken into consideration. In the schools with higher strength, 100 students were selected per school after the exclusion criteria. The selection was done by simple random sampling. The parent/ guardian of the selected students (primary respondent) was contacted and interviewed on the Parent– Teacher Meet with Pre-tested predesigned questionnaire [15,16] with four sections (general information, socioeconomic status, dietary habits, and physical activity). NC was measured as per the method described by Kondolot et al[9]. Height was measured by stadiometer to the nearest centimetre with the child standing erect without shoes. Weight was measured using a digital weighing machine to the nearest 100 grams. WC was measured in centimetres using a plastic tape measured at the midpoint between the costal margin and iliac crest [17]. HC was measured in centimetres with a plastic shape at the prominence of buttocks above the gluteal fold.NC was measured in centimetres using a plastic tape measure while the child's head was held erect with eyes facing forward and the neck in a horizontal plane at the level of the most prominent portion, the thyroid cartilage. BMI, Waist- Height ratio and Waist – Hip ratio was calculated. Based on the observed BMI values, the children were grouped into one of the following categories: Grade I- Risk of overweight, Grade II- overweight, Grade III – obese and Grade IV – apparently normal by referring the WHO BMI for age Z-score charts for the entire study population.[18]

Ethical Considerations: The SMVMCH Institutional Ethics Committee in Puducherry, India, gave ethical and scientific approval prior to the present study's start – SMVMCH-EC/DO/AL1285/10-10-2021.

Statistical Analysis: Anthropometric data were expressed as mean and standard deviation. Association between non-normally distributed variables was derived using the Spearman's rank correlation coefficient. Proportions were compared using the $\chi 2$ test. Centile curves were constructed using the LMS Chart Maker Pro version 2.3 software (The Institute of Child Health, London) which fits smooth centile curves to the reference data. This method summarizes percentiles at each age based on the power of age-specific Box-Cox power transformations that are used to normalize data. Gender differences in Neck circumference (NC) were compared with non-parametric tests. NC cut-off values were calculated for 3-11-year-old children with Receiver Operating

Characteristics (ROC) analysis curve made using SPSS software according to dependent variables overweight and obesity as defined by BMI for age >+1 SD and > +2 SD respectively.

RESULTS

The proportion of school children sampled was almost equal with respect to the type of school (48.6% Government/ 51.4%Private) and gender (56.02% boys and 43.98% girls). The study population was further categorized into three age groups such as 3-5 years, 6-8 years and 9-11 years and the representation by each group was 25.59%, 39.57% and 34.84%. From the anthropometric parameters measured, it was observed that the heights, mean (SD) ranged from 95.17(±4.58) cm to 140.52 (±8.97) cm in boys and 93.08 (±7.67) cm to 140.07(±7.56) cm in girls. The mean BMIs ranged from 16.75 (±2.41) cm to 18.33 (±4.72) cm in boys and from 16.75 (±2.41) cm to 16.95 (±3.55) cm in girls.

Table 1: Age and gender wise mean (with Standard deviation) of the various Anthropometric Indices of the school children

Age	BMI (kg/m²)		WC (cm)		Waist Ht R		HC (cm)		WHR		NC (cm)	
(y)	Boy	Girl	Boy	Girl	Boy	Girl	Boy	Girl	Boy	Girl	Boy	Girl
3	16.75±2.41	16.76±2.75	46.8±5.17	46.93±6.85	0.49±0.05	0.5±0.07	54.0±4.61	54.8±0.64	0.86±0.05	0.85±0.06	23.64±1.16	23.59±1.63
4	15.9±2.59	15.6±2.22	47.06±4.98	47.96±4.49	0.45±0.05*	0.48±0.05*	54.18±4.92	55.4±4.78	0.87±0.04	0.87±0.04	23.76±1.33	23.29±1.21
5	15.34±2.37	16.05±1.92	50.47±8.4	50.69±4.75	0.46±0.08	0.47±0.05	59.42±7.66	61.44±3.87	0.85±0.05	0.83±0.03	24.58±2.14	24.4±1.0
6	14.71±3.04	15.22±2.5	50.15±6.34	51.87±6.17	0.46±0.07	0.48±0.05	58.24±6.01	61.43±6.35	0.86±0.04*	0.84±0.04*	24.78±2.31	25.12±2.05
7	14.95±3.09	15.22±2.85	49.93±7.02	49.35±6.96	0.43±0.06	0.42±0.06	58.78±6.57	60.49±7.76	0.85±0.04	0.82±0.06	24.32±1.71	24.03±1.73
8	16.6±±3.72	16.6±2.91	50.86±9.47	51.56±7.65	0.42±0.08	0.42±0.06	61.51±8.21	63.67±7.69	0.82±0.06	0.81±0.06	25.51±2.36	25.45±1.97
9	15.95±3.28	16.36±3.26	52.15±9.74	51.01±7.45	0.4±0.06	0.4±0.05	65.02±8.65	66.18±7.22	0.8±0.05*	0.77±0.06*	26.03±2.1	25.48±2.09
10	17.85±4.58	17.14±3.51	60.55±10.96	57.16±9.43	0.45±0.08	0.43±0.07	71.68±9.05	71.50±8.69	0.84±0.06*	0.8±0.06*	27.59±2.52	26.67±2.36
11	18.3±4.72	16.9±3.55	63.21±12.19	60.8±10.36	0.45±0.08	0.43±0.07	74.9±9.73	76.1±10.5	0.84±0.07*	0.8±0.05*	28.49±2.87	27.6±2.67

Values are **Mean (SD)**. BMI- Body Mass Index, WC- Waist circumference WHtR- Waist Height Ratio, HC-Hip circumference, WHR- Waist Hip ratio, NC-Neck circumference

Table 2: Age group and Gender-wise correlation (Spearman's Rank Order) of Neck Circumference in children to other anthropometric parameters

Age & Gender	Height (cm)	Weight (cm)	BMI (k/m²)	WC	WHtR	HC	WHR
All boys	0.5350**	0.7850**	0.7123**	0.8442**	0.4946**	0.8551**	0.2606**
All girls	0.5339**	0.7890**	0.7408**	0.8177**	0.3198**	0.8373**	-0.0005^{NS}
3–5-year Boys	0.2511**	0.6290**	0.7111**	0.6845**	0.5467**	0.5521**	0.4517**
3–5-year Girls	0.1738^{NS}	0.6466**	0.7832**	0.6896**	0.5531**	0.6298**	0.2808**
6–8-year Boys	0.0509^{NS}	0.6117**	0.8155**	0.7947**	0.7009**	0.7901**	0.37726**
6–8-year Girls	0.2090**	0.6321**	0.7744**	0.7255**	0.5860**	0.7210**	0.2123**
9-11year Boys	0.3594**	0.8204**	0.8197**	0.8656**	0.8409**	0.8598**	0.6878**
9-11year Girls	0.3683**	0.8373**	0.8615**	0.8848**	0.8315**	0.8911**	0.5102**

BMI (Body Mass Index), WC- Waist circumference, WHtR- Waist Height Ratio,
HC-Hip circumference, WHR- Waist Hip ratio, NC-Neck circumference
Spearman's Rank Order correlation, **** P<0.001**

Table 3: Age-wise neck circumference percentile values for boys

Age (year)	Percentiles for neck circumference (Boys)							
	3	10	25	50	75	85	90	97
3	21.78	22	22.85	23.6	24.5	25	25	25.24
4	21.34	22	23	23.8	24.6	25	25.51	26
5	21.70	22.42	23.13	23.85	25.9	27.23	27.53	28.29
6	21.50	22.02	22.7	24.8	26.8	27	27.9	28.72
7	21.88	22.5	23	23.8	25.63	26	26.6	27.11
8	22.5	23	24	25.2	26.8	27.96	28.52	30.36
9	23.0	24	24.575	25.5	26.98	28.43	29.4	30.35
10	24.0	24.21	25.5	27	29.63	30.5	30.88	32.11
11	24.39	25	26.45	28.35	30.15	31.17	32.42	34.11

Table 4: Age-wise neck circumference percentile values for girls

Age (Year)	Percentile for neck circumference (Girls)							
	3	10	25	50	75	85	90	97
3	19.785	21.8	23	24	24.5	25	25.05	25.76
4	21.5	22	22.5	23.3	24	24	24.88	26
5	23.11	23.35	23.88	24.25	24.9	25.46	25.65	25.89
6	21.96	22.3	23.33	25	26.77	27.7	27.91	28
7	21.5	22	22.9	23.75	24.85	26.17	26.66	27.73
8	22.44	23	24	25	26.72	27.81	28.31	29.63
9	22.36	23	24	25.25	27.22	27.67	28	28.73
10	23.02	23.6	25	26.5	28	29	30.14	31.26
11	24	24.3	25.6	27.5	29	30.38	31.48	32.87

Table 5: Area Under Curve (AUC) for predicting overweight and obesity based on the neck circumference in school children categorized by age and sex

Age-group (n)	AUC	SE	95% C. I.	Sensitivity	Specificity	Cut-off value	P value
Overweight							
3 -5 years (34)							
Boys (24)	0.916	0.028	0.86-0.97	87.5%	87.6%	>24.5	**0.001**
Girls (10)	0.953	0.027	0.89-1.00	80.0%	95.59%	>24.5	**0.001**
6-8 years (57)							
Boys (31)	0.870	0.027	0.81-0.92	100%	60.14%	>24.5	**0.001**
Girls (26)	0.927	0.020	0.88-0.97	100%	82.26%	>25.5	**0.001**
9-11years (62)							
Boys (34)	0.917	0.02	0.86-0.96	91.18%	83.19%	>27.5	**0.001**
Girls (28)	0.872	0.02	0.81-0.92	100%	64.34	>26.5	**0.001**
Obesity							
3 -5 years (17)	0.906	0.03	0.83-0.97	87.755%	76.58%	>24.50	**0.001**
Boys (12)	0.851	0.05	0.74-0.96	81.82%	69.35%	>24.50	**0.001**
Girls (5)	0.984	0.01	0.96-1.0	100%	95.92%	>25.25	**0.003**
6-8 years (39)	0.942	0.018	0.90-0.97	82.05%	93.62%	>27.50	**0.001**
Boys (23)	0.941	0.02	0.88-0.99	82.61%	94.41%	>27.50	**0.001**
Girls (16)	0.943	0.02	0.89-0.98	81.25%	92.67%	>27.50	**0.001**
9-11years (42)	0.929	0.01	0.89-0.96	90.48%	80.50%	>28.50	**0.001**
Boys (31)	0.912	0.02	0.86-0.96	80.65%	84.31%	>29.50	**0.001**
Girls (11)	0.959	0.01	0.91-0.99	100%	86.05%	>28.50	**0.001**

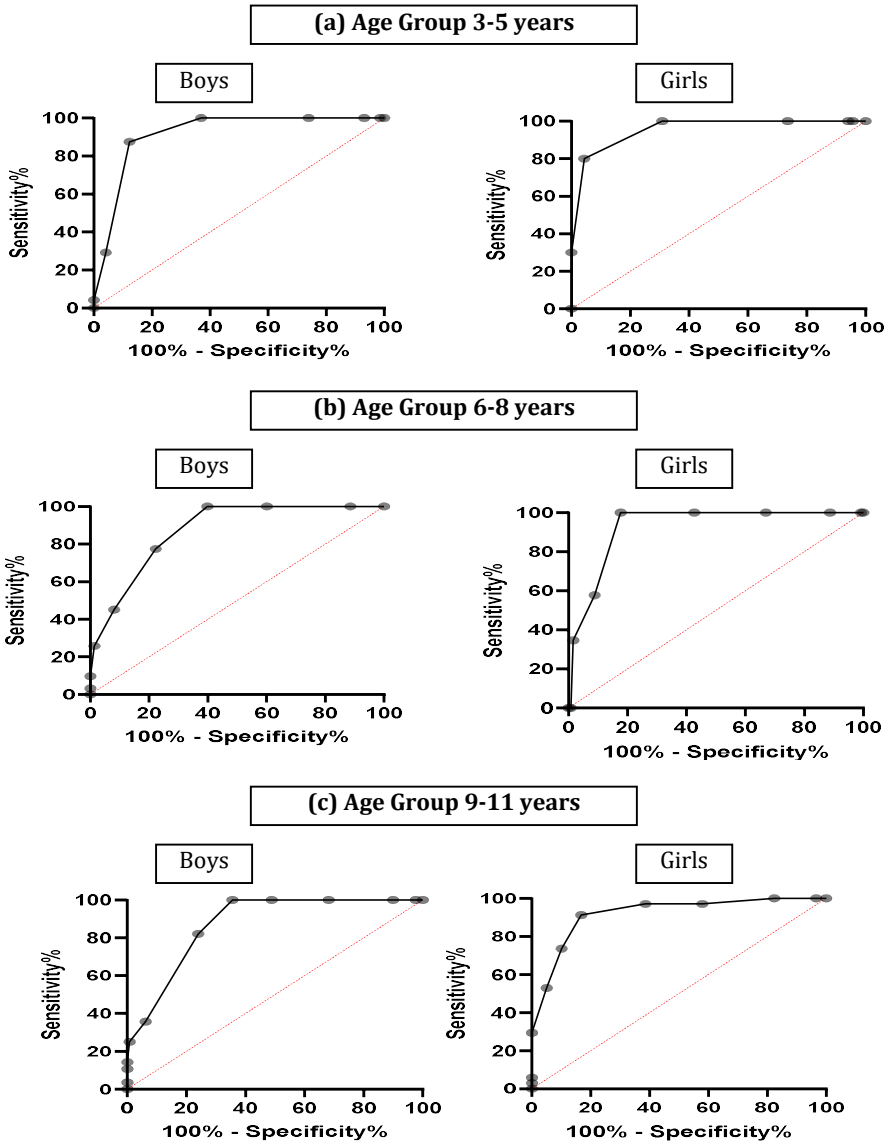

Fig 1: ROC curve of neck circumference for predicting Overweight in school children in the three different age groups 3-5y (a) 6-8y (b) and 9-11y(c) for boys and girls respectively.

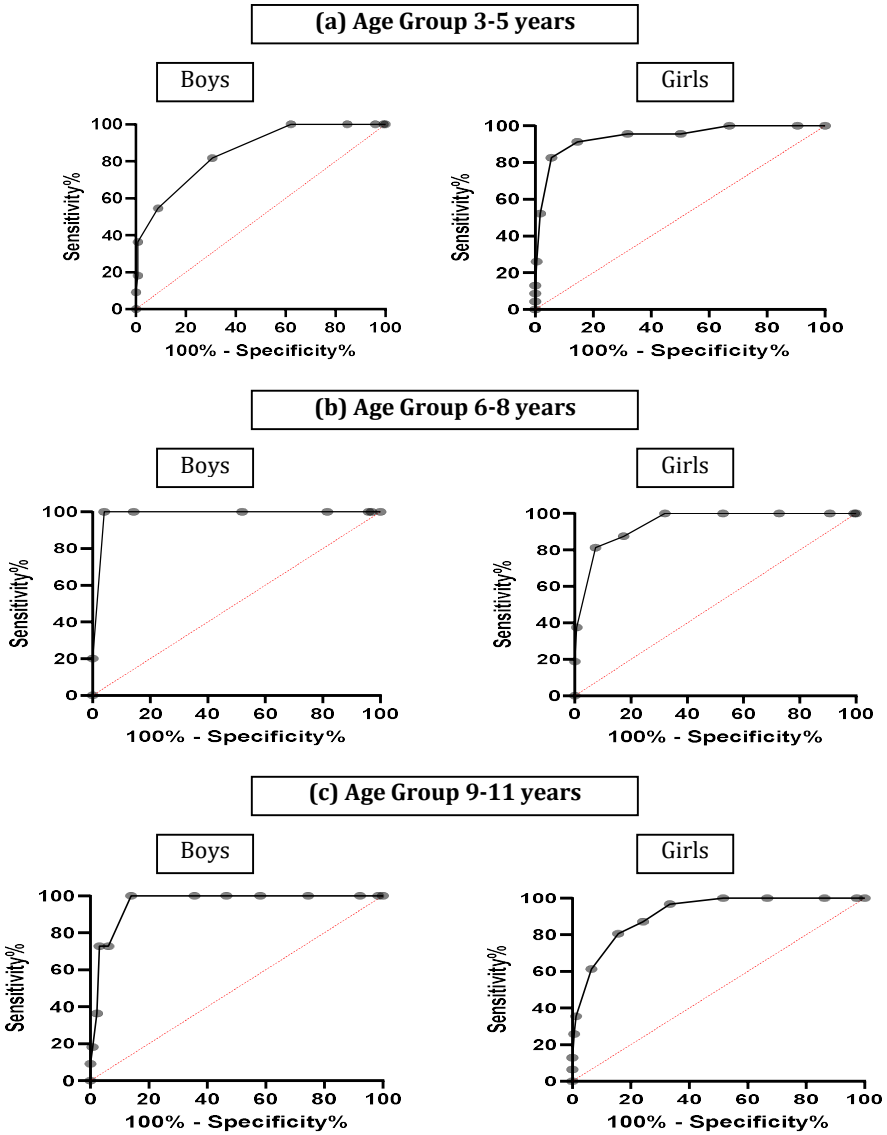

Fig 2: ROC curve of neck circumference for predicting Obesity in school children in the three different age groups 3-5y (a), 6-8y (b) and 9-11y(c) for boys and girls respectively

The mean WC in boys ranged from 46.8 (±5.17) cm to 63.21 (±12.19) cm and 46.93(±6.85) cm to 60.8 (±10.36) cm in girls and followed a gradual increase in values with age. The NC measurements ranged from 23.64(±1.16) cm to 28.49(±2.87) cm in boys and 23.59(±1.63) cm to 27.6 (±2.67) cm in girls (Table 1). The NC values showed significant correlation (P<0.01) to the other anthropometric parameters and gender-wise across the three age groups (Table 2)

The NC values in the overweight and obese children of the 6–8-year-old age-group were significantly higher (p=0.006 and p= 0.0001) than those of age-matched apparently normal children. However, there were no significant differences in the NC values between the overweight and obese children.

The NC values in the overweight and obese children of the 9–11-year-old age-group were significantly higher (p=0.0004 and p<0.0001) than those of age-matched apparently normal children, but no significant differences in the NC values between the overweight and obese children in the 9–11-year-old age-groups

Of the total number of 930 children studied 633 (68.06%) were apparently normal, the percentage of boys and girls being 340 (53.71%) and 293 (46.28%) respectively.

The age and gender specific 3rd, 10th, 25th, 50th, 75th, 85th, 90th and 97th percentile values for NC in children are shown in Table 3 & Table 4.

The NC percentile values from the model, tended to be larger with increasing age and generally higher in females compared to males. The range of NC (5th to 95th estimates) in males was higher than in females, particularly for those approximately age 10 years and older.

The area under the curve (AUC) of more than 87 % and more than 85% for the NC values using ROC among both boys and girls, indicate the accuracy of

the parameter to identify children with a high BMI and to predict overweight and obesity respectively. The AUC for overweight and obesity in the three age groups of both sexes is shown in Fig 1 and 2. Cut-off points of NC to predict the presence of overweight and obesity with their corresponding specificity and sensitivity by gender in each age group is shown in Table 5.

A progressive increase in the cut-off values of NC was observed in both male and female children.

Using the reference percentile data and curves, and the cut –off values obtained by ROC analysis, it may be inferred that a NC above the 75th percentile for age and gender could be regarded as overweight and above the 90th percentile as obese in both boys and girls (Corresponding to BMI > +1SD and >+2SD).

Discussion

Unlike adults, children are classified based on their age by using percentiles or Z scores. The percentile records an individual's position in the growth chart. Z scores define the anthropometric value based on standard deviations from the reference mean or median.[19,20] BMI for age Z scores was available for ages 5-19 by WHO, younger children were defined based on weight/height. In 2007, BMI for age Z scores for ages 0-5were also developed.[19,20] The usage of WHO BMI-for- age Z score cut-offs in this study, to define overweight/obesity for the entire study population supports wider acceptability and feasibility, because of the usage of a single standard formula to categorize the complete study group (3-11years); and for comparing with other studies and populations when the need arrives for achieving a single consensus.

With these values, the overall prevalence of overweight and obesity in the study population was observed as 16.45% and 15.4%. A multicentric study in Indian children between 2-17 years of age demonstrated a prevalence of 18.6% (IOTF definition) and 23.6% (WHO definition).[7] Studies by Rajagopalan et al in urban and rural children in Puducherry determined a prevalence of obesity of 12.3%, 19.4% and 6.4 %, 19.3% in boys and girls from urban and rural areas aged 8-13 years based on WHR .[20] Study from Puducherry by Verma et al revealed a prevalence of 4.98% and 2.24% in males and females in the 8-13 age groups.[14]

Studies of late have questioned the validity of BMI, a measure of central obesity, but unable to assess visceral/ abdominal obesity and total body fat, thereby not accepted as a sensitive/ specific indicator of cardiovascular or other co-morbid risks. Alternate anthropometric parameters have been studied of late, the recent one being NC, that this study chose to analyze for validation.

Our study on NC and its influences on other indicators of obesity were studied among the age group 3-11 years for which comparable data from literature is scarce. Hence, the data variables were critically analyzed to assess if they are in accordance with other reference populations for future studies.

Parameters such as height, weight, BMI etc were analyzed. It was observed that measurements such as height, weight, BMI etc. showed a normal distribution and the values gradually increased with age. The BMI was found to show a decreasing trend by approximately 2 kg/m^2 at five to six years of age in boys, following which it progressed in an increasing manner. This is consistent with the physiological phenomenon of 'adiposity rebound' seen in BMI values at this age.[16]

The mean and SD of NC were higher in boys compared to girls. This gender difference showed in the study was similar to that of most of the previous studies in similar age groups represented by Kondolot et al, Kelishadi et al and Sreelatha et al.[9,13,22] The study on children aged two to six years by Kondolot et al[9], recorded a difference of 1.4cm between the means of NC in boys and 0.5 cm in means of NC in girls.[9] The present study on 3-11-year-old children showed a mean difference in NC of 4.85 cm in boys with a difference of 1.87 cm during3-8 years and 2.98 cm from 9 -11 years. In girls, the difference of means of NC between 3-11 years was 4.01cm, with 1.86 cm being the difference in 3-8 years age and 2.15 cm increase in the mean NC from 9-11 years. This wider difference in the overall measurements after eight years of age can be attributed to the fact that the growth spurt occurs during this age period, overweight/obesity and other bodily changes are more pronounced clinically as the child grows.

The 3rd, 10th, 25th, 50th, 75th, 85th, 90^{th,} and 97th percentile values for age were generated. These cut off values were found to be slightly lower in boys than in girls. Minimum and maximum differences between the 90th centile and 3rd centile for boys are at three years (3.22cm) and eleven years (8.03cm). Girls the minimum difference was at five years (2.54 cm) and the maximum at eleven years (7.48 cm). The increase in the 50th percentile value from 3 years to 11years was 4.75cm in boys and 5cm in girls.

In the study by Kondolot et al[9], a mean increase in the 50th centiles for boys and girls from two-six years was 1.4 and 0.6. Our study also showed an increase of 1.2 cms and 1cm in the 50th centile values in boys and girls from three to six years thus supporting almost similar trends.

The NC values were correlated with the other anthropometric parameters such as height, weight, BMI etc. The correlation was carried out for the entire study group, followed by gender differences within the three subgroups (3-5 years, 6-8 years and 9-11 years). Except the heights of girls of 3-5 years and boys of the 6-8year groups, all other parameters had a statistically significant positive correlation ($p<0.05$) with NC values in both the genders. The strongest association was found to be with BMI followed by waist circumference. Previous studies in

similar younger age groups conducted outside India[9,13] in the 13–17-year age groups in India by Patnaik et al., Yashoda et al., Rajagopal et al.[11,12,21], and in 6–16-year-olds by Sreelatha et al[13] also showed positive associations with NC and these indices.

The strong correlation with BMI, which was the reference for defining overweight and obesity in this study population, paves way for the utilization of NC and also to define overweight/obese children in the three age groups.

ROC analysis carried out to validate the optimal cut-off point to determine overweight and obesity in the three age groups had estimated cut-offs with AUC (Area under Curve) values of 0.9 and above, with significant p-value, proving to be highly sensitive and specific for validating the usage of NC in classifying the children into overweight and obese.

Incorporating the above-mentioned cut-off values in the designed percentile charts for NC, for boys and girls respectively; it was observed that values above the 75th percentile for age and gender could be regarded as overweight and above the 90thpercentile as obese in both boys and girls. In totality, the values at or above the 75th percentile are to be monitored for overweight/obesity in their specific age groups. The observations made in this study show similar trends as reported by Kondolotet al[9] for 2–6-year children from Turkey, and in older children by Hassanet al[23], Pei et al[24], Katz et al[25] and Kelshadi et al[21] from different parts of the world.

Owing to the scarcity of literature of similar studies, this study lacks external validation and needs to be backed up by further evidence. Even though the sample size of this study was 930, further similar studies in similar and older age groups from various ethnical regions are needed for developing this anthropometric measure as a universal screening tool.

Conclusion

Neck Circumference can be validated as an anthropometric indicator for overweight/ obesity in pre- and primary school children. Strong positive correlation with already existing indicators such as BMI and Waist circumference and WHR suggest that it may be used as an independent tool to screen for obesity. Measuring and plotting the individual child's neck circumference against the reference charts for age and sex can predict overweight and obesity if the value falls above the 75th and 90th centile respectively. Usage of this simple and effective screening tool in the identification of this multi-faceted condition paves way for early intervention.

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