# Neck circumference and waist circumference as a tool for evaluating obesity

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## ABSTRACT

**Background:** Obesity has acquired an epidemic proportion, leading to increased morbidity and mortality. Early identification and timely intervention in children are the need of the hour. **Objective:** The objective of the study was to measure and compare the neck circumference (NC) and waist circumference (WC) in normal, overweight, and obese children followed by their correlation with body mass index (BMI). **Materials and Methods:** This cross-sectional study was conducted in 1000 school-going children of 6–14 years age group. Their BMI, NC, and WC were measured, compared, and correlated by appropriate statistical analysis. **Results:** The difference between NC and WC of overweight and obese children and that of normal children was statistically significant and the measurements correlated with the BMI. The age-wise cutoff values of NC and WC in male and female children were calculated along with their sensitivity and specificity for detecting obesity. **Conclusion:** NC and WC are practical, efficient, and cost-effective tools to identify obesity amongst school-going children.

**Key words:** *Obesity, Body mass index, Neck circumference, Waist Circumference*

Childhood obesity is a growing global public health concern. According to the World Health Organization (WHO), over 340 million children and adolescents aged 5–19 years were overweight or obese in 2016 [1]. Its association with several conditions such as diabetes mellitus, hypertension, and coronary artery disease later on in life is well established. Initially considered a disease of developed countries, it has paved its ways into the developing countries like India [2]. This trend is observed more so in urban areas with adequate wealth and easy availability of resources.

Conventional indicators such as body mass index (BMI), skinfold thickness, waist circumference (WC), and waist-hip ratio are used for the measurement of overweight and obesity [2]. Although BMI is the most widely used tool, it is a suboptimal marker for total body fat and less suitable to assess body fat distribution.

Regional deposition of fat, especially in the upper body segment, is a better predictor of obesity-related complications [3]. Hence, neck circumference (NC) has been suggested as an index of upper body fat distribution as subcutaneous fat releases more free fatty acid in upper part of the body than its lower part [4]. WC is used as a tool to measure central obesity as it suggests continuous deposition of fat with increasing age and waist size [5,6]. The measurement of NC and WC by a simple measuring tape is relatively easy and has not been explored adequately as an anthropometric measure of overweight and obesity. This study was performed to outline the importance of NC and WC as a tool for evaluating overweight and obesity amongst school-going children.

## MATERIALS AND METHODS

This cross-sectional, observational study was conducted from January 2018 to June 2019 in six schools of Jaipur, Rajasthan after obtaining prior written consent from the school authorities and the parents/guardians of the study subjects. The sample size consisted of 1000 children ranging from 6 to 14 years of age. The sample size was estimated for infinite population using the formula $4pq/d^2$ where prevalence was taken as 10% [7]. The required precision of the estimate (d) was set at 20%. Using the above-mentioned formula, the sample size was estimated to be 900. After adding the non-response error of 10%, an additional 100 subjects were included. Thus, 1000 subjects were selected for this study.

All healthy school-going children, without any history of hospitalization due to any reason, were included. The children with conditions such as any swelling or cysts in the neck region, for example, goiter and craniovertebral anomalies that could interfere with measurement of NC were excluded from the study. Patients with nephrotic syndrome, Cushing's syndrome, and those with exogenous steroid intake which may have interfered with the measuring of WC were excluded from the study. Children with acute or chronic illnesses such as malnutrition, HIV, and malignancy were also excluded from the study. The study was approved by the Institutional Ethical Committee.

To measure height, all the study subjects were asked to remove their shoes and to stand barefoot with their head, shoulders, buttocks, and feet together against the wall on a portable plastic stadiometer with head held in the Frankfort horizontal plane and the height was measured to the nearest 0.1 cm. An electronic weighing machine (SecaGmB and Co Kg®, Hamburg, Germany) was used to measure weight of all the children without shoes in light clothing to the nearest 0.1 kg accuracy. BMI was calculated using the standard formula:

BMI = Weight (in kg)/[Height (in m)]$^2$

The calculated BMI for each child was plotted on the revised IAP-WHO growth charts 2015 for BMI [8]. Accordingly, the study subjects were classified into the respective categories as normal, overweight, and obese. The BMI centiles used for categorization as per the revised IAP-WHO 2015 [8] growth charts were as follows:

- Below 23$^{rd}$ Adult equivalent: Normal
- 23$^{rd}$ to below 27$^{th}$ Adult equivalent: Overweight
- 27$^{th}$ Adult equivalent and above: Obese

Using a non-stretchable plastic measuring tape, NC was measured in cm at the level of the thyroid cartilage with the child in standing position, head held erect, and eyes facing forward in a horizontal plane while the WC (in cm) was measured using the same measuring tape to the nearest level of 0.1 cm at the midpoint between the iliac crest and the inferior margin of the lowest rib in midaxillary line at the end of normal expiration in standing position.

All statistical tests were carried out using the SPSS version 21.0 software. All categorical and continuous measurements were computed and presented in number (%) and mean ± SD, respectively. To study the significance of parameters on a continuous scale between two groups, two-tailed Student's t-test was used. However, to find the degree of relationship between various anthropometric measurements, Pearson's correlation was used. $p<0.05$ was considered statistically significant.

## RESULTS

A total of 1000 school-going children comprising 449 males and 551 females in the age group of 6–14 years were included as the study subjects. M:F ratio was 0.81:1. In this study, individuals were categorized according to BMI grades into normal, overweight, and obese. The mean NC and WC of obese and overweight male and female study subjects were compared with that of the children with normal BMI (Table 1) and the difference was statistically significant.

The degree of correlation of BMI with NC and WC was calculated using Pearson's correlation (Table 2).

BMI was positively correlated with NC and WC in both male and female children. The age-wise cutoff values for NC and WC with respective sensitivity and specificity for identifying children with obesity have been mentioned (Tables 3 and 4).

## DISCUSSION

Obesity has acquired an epidemic proportion and requires worldwide attention from all the nations as its prevalence of obesity has risen dramatically among children and adolescents. In 2016, 18% of girls and 19% of boys were found to be overweight while 6% of girls and 8% of boys were obese [1]. Studies performed on obesity in childhood have proven beneficial as they may help in the early identification of overweight and obese children, and also in initiating, the interventional measures before the harmful sequelae can occur [5,9-17]. This study evaluated NC and WC as a marker of obesity and suggestive cutoff values for the same.

The results of this study together with those of the nearly identical studies done earlier in various countries indicate that

**Table 1: Anthropometric measurements in the school-going children in the present study**

| Attributes | Normal BMI (n=792) | Overweight (n=112) | Obese (n=96) | p-value |
|---|---|---|---|---|
| Male (n) | 364 | 44 | 41 | |
| Mean age | 10.02±2.5 | 10.2±2.68 | 9.44±2.23 | <0.001 |
| BMI* | 16.73±2.03 | 20.01±2 | 23.22±2.61 | <0.001 |
| NC# | 28.53±2.15 | 30.22±2.33 | 30.44±1.7 | <0.001 |
| WC$ | 60.89±10.02 | 67.31±12.94 | 68.16±11.76 | <0.001 |
| Female (n) | 428 | 68 | 55 | |
| Mean age | 10.4±2.29 | 9.9±2.37 | 9.56±2.15 | <0.001 |
| BMI | 17.44±2.31 | 21.19±2.55 | 24.67±2.51 | <0.001 |
| NC | 28.58±1.87 | 29.65±2.11 | 30.44±1.77 | <0.001 |
| WC | 60.54±9.62 | 62.21±12.03 | 65.71±10.35 | <0.001 |

All values in mean±SD; Age in years, BMI* in kg/m², NC# and WC$ in cm. BMI: Body mass index

**Table 2: Correlation between BMI and NC and WC**

| Karl Pearson's correlation "r" | BMI versus NC | p-value | BMI versus WC | p-value |
|---|---|---|---|---|
| Male | 0.75 | <0.001 | 0.77 | <0.001 |
| Female | 0.76 | <0.001 | 0.83 | <0.001 |

BMI: Body mass index, NC: Neck circumference, WC: Waist circumference

NC and WC increase with the age of male and female children and both these parameters are strongly correlated with BMI (Tables 5 and 6). NC, as a new parameter has shown good results in clinical practice and in epidemiological studies as a marker for central obesity.

The comparison of cutoff values of WC of this study with other studies (Table 6) should be interpreted with caution because different sites for measurement of the parameter have been used. McCarthy *et al.* [23] and Taylor *et al.* [5] have used different reference points as compared to other studies. These differences suggest the need for more standardized and universally agreed on definition for reference points for the measurement of WC. Further, there were significant differences in the observed values of WC in studies performed in Asian countries [18,20-22] from the Western world [5,19,23]. This may be explained by variation in diet, physiological activity, early growth rate, and genetic influences.

Patnaik *et al.* [9] in their study used the NC and WC as an index of overweight and obesity among school-going adolescents and they observed them to be significantly higher in obese adolescents than those with normal BMI ($p<0.001$) which was in accordance with this study.

According to Karl Pearson's correlation "r," there is a very strong correlation between BMI with NC and WC for both male and female children. This observation is in consonance with other studies (Table 7). Lou *et al.* [12], on the basis of "r," concluded that there was a significant correlation between BMI-NC in both male and female study subjects.

**Table 3: Cutoff values of NC and WC for males according to sensitivity and specificity**

| Age | NC (cm) | | | WC (cm) | | |
|---|---|---|---|---|---|---|
| | NC (cm) | Sensitivity (%) | Specificity (%) | WC (cm) | Sensitivity (%) | Specificity (%) |
| 6 years | 27.25 | 75 | 90.2 | 49.75 | 83.3 | 73.2 |
| 7 years | 28.25 | 87.5 | 97.6 | 53.50 | 75 | 70.7 |
| 8 years | 28.40 | 89.2 | 82.4 | 55.50 | 62.5 | 83.9 |
| 9 years | 29.20 | 78.42 | 80.25 | 57.10 | 80 | 73.2 |
| 10 years | 29.80 | 81.26 | 78.9 | 61.40 | 82.45 | 82.16 |
| 11 years | 31.60 | 100 | 94.8 | 61.92 | 81.12 | 78.02 |
| 12 years | 31.82 | 82.45 | 80.52 | 63.50 | 76.82 | 78.42 |
| 13 years | 32.08 | 78.55 | 80.24 | 72.28 | 76.90 | 80.04 |
| 14 years | 32.42 | 76.12 | 79.19 | 74.35 | 84.52 | 80.25 |

NC: Neck circumference, WC: Waist circumference

**Table 4: Cutoff values of NC and WC for females according to sensitivity and specificity**

| Age | NC (cm) | | | WC (cm) | | |
|---|---|---|---|---|---|---|
| | NC (cm) | Sensitivity (%) | Specificity (%) | WC (cm) | Sensitivity (%) | Specificity (%) |
| 6 years | 24.26 | 81.12 | 78.02 | 45.12 | 75.90 | 81.08 |
| 7 years | 26.20 | 76.82 | 78.42 | 46.02 | 80.24 | 78.02 |
| 8 years | 27.14 | 76.90 | 80.04 | 48.14 | 82.26 | 79.9 |
| 9 years | 28.02 | 80.12 | 78.02 | 52.20 | 100 | 93.8 |
| 10 years | 28.40 | 81.26 | 78.9 | 56.40 | 83.45 | 84.52 |
| 11 years | 28.82 | 100 | 93.8 | 61.28 | 78.65 | 80.24 |
| 12 years | 29.04 | 84.45 | 80.52 | 63.26 | 76.72 | 74.42 |
| 13 years | 29.48 | 78.65 | 80.24 | 66.52 | 76.90 | 80.04 |
| 14 years | 30.22 | 80.26 | 79.9 | 70.75 | 81.12 | 60.20 |

NC: Neck circumference, WC: Waist circumference

**Table 5: Comparison of cutoff values of NC in various studies**

| Author | Place/Year | Age group; sample size (n) | Suggested cutoffs of NC* (cm) | |
|---|---|---|---|---|
| | | | Male | Female |
| This study | India (2019) | 6–14 years; (n=1000) | 27.25–32.42 | 24.26–30.22 |
| Patnaik *et al.* [9] | India (2017) | 10–16 years; (n=1800) | 30.75 | 29.75 |
| Taheri *et al.* [10] | Iran (2013) | 6–17 years; (n=864) | 27.50–38.3 | 26.7–33.4 |
| Atwa *et al.* [11] | Egypt (2012) | 12–15 years; (n=2762) | 29.3–31.7 | 28.6–31.4 |
| Lou *et al.* [12] | China (2011) | 7–12 years; (n=2874) | 27.4–31.3 | 26.3–31.4 |
| Olubukola *et al.* [13] | USA (2010) | 6–18 years; (n=1102) | 28.5–39.0 | 27.0–34.6 |
| Hatipoglu *et al.* [14] | Turkey (2010) | 6–18 years; (n=976) | 28.0–38.0 | 27.0–34.5 |

NC: Neck circumference

**Table 6: Comparison of cutoff values of WC in various studies [5,18-23]**

| Authors | Place/Year | Age group; sample | Anatomic point of measurement | Suggested cutoffs of WC* (cm) | |
|---|---|---|---|---|---|
| | | | | Male | Female |
| This study | India (2019) | 6–14 years; (n=1000) | Midpoint between lower rib cage and iliac crest | 49.75–74.35 | 45.12–70.75 |
| Patnaik *et al.* [9] | India (2017) | 10–16 years; (n=1800) | Midpoint between costal margin and iliac crest | 70.75 | 69.25 |
| Hatipoglu *et al.* [18] | Turkey (2013) | 0–6 years; (n=2947) | Midpoint between lower rib cage and iliac crest | 33.6–59.7 | 34.9–59 |
| Mederico *et al.* [19] | Venezuela (2013) | 9–18 years; (n=919) | Midpoint between costal border and iliac crest | 69.2–86.7 | 69.7–83.6 |
| Kuriyan *et al.* [20] | India (2011) | 3–16 years; (n=9060) | Midpoint between lower rib cage and iliac crest | 51.1–81.3 | 51.8–79 |
| Poh *et al.* [21] | Malaysia (2011) | 6–16.9 years; (n=16,203) | Midpoint between last rib and upper iliac crest | 60.8–90.2 | 57.9–80.8 |
| Mushtaq *et al.* [22] | Pakistan (2011) | 5–12 years; (n=1860) | Midpoint between last rib and upper border of iliac crest | 59.1–76.2 | 58–79.4 |
| McCarthy *et al.* [23] | UK (2001) | 5–16.9 years; (n=8355) | Midpoint between $10^{th}$ rib and iliac crest | 57–85.2 | 57.2–75.1 |
| Taylor *et al.* [5] | NewZealand (2000) | 3–19 years; (n=380) | Minimum circumference between iliac crest and rib cage | 45.8–113 | 46.5–112.6 |

WC: Waist circumference

**Table 7: Comparison of Pearson's correlation (r) of this study with other studies [9,14]**

| Age* | BMI-WC | | | BMI-NC | | | NC-WC | | | p-value |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C | |
| Males | | | | | | | | | | |
| <10 | 0.73 | 0.897 | −0.693 | 0.71 | 0.700 | −0.642 | 0.70 | 0.733 | - | <0.001 |
| >10 | 0.81 | 0.948 | | 0.79 | 0.821 | | 0.80 | 0.839 | - | <0.001 |
| Females | | | | | | | | | | |
| <10 | 0.79 | 0.881 | −0.682 | 0.68 | 0.727 | −0.615 | 0.74 | 0.776 | - | <0.001 |
| >10 | 0.88 | 0.925 | | 0.83 | 0.848 | | 0.84 | 0.854 | - | <0.001 |

*Age in years; A=This study; B=Hatipoglu *et al.*; C=Patnaik *et al.*; BMI: Body mass index, NC: Neck circumference, WC: Waist circumference

The large-scale data of anthropometric measurements such as BMI, NC, and WC may be utilized to predict occurrence of cardiometabolic complications later on in life according to studies conducted in infants [16]. Sardinha *et al.* [17] conducted a study of comparison between BMI, WC, and waist-to-height ratio for identifying cardiometabolic risk in children and adolescents and found markedly steeper positive slope between anthropometric variables and all cardiometabolic risk factors suggesting increase in risk factors at a higher end of BMI/adiposity distribution.

The study had a few limitations. It had a small sample size due to constraints of time and logistics along with an absence of rural and urban stratification, leading to generalization of eating pattern and activity levels of the whole population. Further, there was lack of validation of the results obtained with functional consequences of obesity. However, this study has important implications despite the limitations and points toward the use of NC and WC as alternative tools in detection of obesity.

## CONCLUSION

Childhood obesity can be prevented by its early identification in school-going children. The NC and WC are simple, efficient, and cost-effective measures to identify obesity in pediatric population. Studies involving a larger sample size are required in Indian set up to further validate the results.

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