UTILITY OF NECK CIRCUMFERENCE AS A SCREENING TOOL FOR OBESITY AND ITS ASSOCIATION WITH HYPERTENSION IN SCHOOL GOING CHILDREN 6-16 YEARS OF AGE

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ABSTRACT

Introduction: The rise in prevalence of obesity among children is increasing globally and is associated with a concomitant increase in co-morbidities and thus increased cardiovascular mortality. Neck circumference is a simple, easy to perform tool which is feasible for implementation in clinical out-patient settings. Hence this study seeks to assess the value of neck circumference in predicting obesity and hypertension among children.

Material and methods: A community based cross-sectional study was conducted on children aged between 6 to 16 years, attending selected schools. Neck circumference was measured at the level of cricothyroid using an inch tape. The relevant information was collected and documented in structured proforma. IBM SPSS version 22 was used for statistical analysis.

Results: 940 participants were included, in which 470 (50%) participants were males, and 470 (50%) participants were female. The mean age was 11.03 ± 3.19. A moderate positive correlation between BMI and neck circumference (r-value: 0.552, P value: <0.001) was observed. This study demonstrates the importance of NC in adolescents. It has highly significant positive correlations with body weight. So, NC can be considered as a good indicator and predictor for obesity and hypertension.

KEY WORDS: Neck circumference, Cricothyroid, Obesity

INTRODUCTION

The prevalence of obesity in the pediatric age group is increasing globally. The rise in prevalence of obesity among children is associated with a concomitant increase in comorbidities and thus increased cardiovascular mortality.\(^1\) The increased prevalence of obesity among children in the past few decades is because of a web of interactive factors such as genetics, dietary habits, increased sedentary lifestyle and environmental influences. Lesser opportunities for energy expenditure involving activities, together with increased intake of calories through diet has resulted in the obesity epidemic among children and adolescents. During the childhood period, obesity results in consequences such as the early onset of puberty and increased risk of insulin resistance. When these children grow up to be adults, they are at an increased risk of carcinomas due to the inflammatory changes occurring in the body.\(^1\)

According to the report on obesity released by the World Health Organization, in the year 2016 alone, 4.1 crores of children under 5 years of age were either overweight or obese globally. Among those in the 5 to 19 years age group, the prevalence is much higher at 34 crores. In the past 4 decades alone from 1975 to 2016, there has been a three-fold increase in the prevalence of obesity. The proportion of obese adolescents has increased from 4% during the year 1975 to as high as 18% in 2016. This is reflected by the fact that in the year 1975, less than 1% of those in the pediatric age group were obese, while as of 2016, more than 126 million children in the pediatric age group were obese.\(^2\) Childhood and adolescent obesity is equally prevalent among both genders. This increase in prevalence not only affects the developing countries but also affects the developing and underdeveloped countries as well. Obesity is more common in urban areas, compared to rural areas.

Currently, in most countries except those in Sub-Saharan Africa, obesity and overweight is responsible for a higher mortality rate than undernutrition and being underweight.\(^3\) According to Kopelman et al\(^4\) (2000), obesity is becoming increasingly prevalent all over the world, that now it has superseded other causes of mortality such as infectious diseases or undernutrition. Obesity is linked with multiple consequences such as cancer, diabetes, metabolic syndrome, cardiovascular diseases and sleep related breathing disorders such as obstructive sleep apnea. Not only obesity, even mild degrees of overweight, increased abdominal fat deposition are also associated with increased morbidity, which has been underestimated so far. The present worldwide epidemic of overweight and obesity among children is a combination of risk factors such as genetics, dietary factors such as increased consumption of calorie-dense foods along with the reduced physical activity. Hence it has been emphasized that childhood obesity should be regarded as a serious epidemic which needs immediate attention.\(^4\)
Obesity, as defined by increased Body Mass Index, has been indirectly associated with adiposity. There are variations according to age, gender and factors such as race. Body fat deposition acts as a strong risk factor for morbidity. Hence BMI has initially used an important screening tool for assessing obesity and implementing the appropriate intervention measures. But later, studies demonstrated that BMI was unable to distinguish between muscle and fat in terms of body weight and hence was a poor predictor of obesity among children. BMI was found to be inadequate in assessing the relative body fat content in children. Hence other screening tools were needed for measurement of adiposity in the pediatric age group.

Clinical tools such as CT, MRI imaging, Dual-energy X-ray absorptiometry can estimate the body fat directly. Other methods include air displacement, plethysmography and hydrodensitometry. But these are more time consuming, require equipment and trained operators. They cannot be implemented on a large scale. Hence, surrogate markers such as anthropometric measurements are other tools for assessing obesity among children. Waist circumference, waist-hip ratio and waist-height ratio have been used commonly to assess obesity and cardiovascular risk. But they have equivocal results from various studies, and there may be variation between genders and ethnicities, and hence optimal cut-offs determined so far have not been validated completely.

To overcome these hurdles, neck circumference has been shown to be easy to apply in a clinical setting and does not require additional expensive resources. This is further strengthened by the fact that the release of free fatty acids is more on the upper half of the body than the lower half, demonstrating the superiority of neck circumference relative to waist circumference and waist-hip ratio. It is also a stronger independent predictor of cardiovascular risk compared to other anthropometric indices such as BMI and waist circumference.

**MATERIALS & METHODS**

**Study area:** The study was a community based cross-sectional study, conducted across selected schools. Study population: Children aged between 6 to 16 years, attending the selected schools were considered as the study population. Study duration: The study was conducted from January 2018 to June 2019 for a period of 18 months.

**Sample size:** The sample size was calculated assuming the expected sensitivity of best cut off value of neck circumference in diagnosis childhood obesity as 81.82% and expected specificity as 89.06%. The expected prevalence was assumed to be 13.2% as per the study by Yashoda et al. The other parameters considered for sample size calculation was 10% precision and 95% confidence level. As per the above-mentioned parameters, the required sample size would be 940 subjects.
Sampling method: The sampling method used was multistage simple random sampling. First stage: The list of the schools in both the government and private sector, located in the chosen geographical area were obtained from the office of respective authorities. From the list, 2 governments and 2 private schools were selected by simple random sampling. Second Stage: In the second stage, the selected schools were visited, and the necessary administrative approval was sought from the school authorities to conduct the study. After the approval, the list of all the students in the school was prepared, and a serial number was allocated to each student. A total of 940 students were sampled from all the schools by simple random sampling probability proportionate the size (PPS), i.e. the strength of the school.

Ethical issues: Approval of institute Human Ethics committee, of Chettinad Hospital and Research Institute, Chennai, was obtained. Informed written consent was obtained from the parents or guardian of all the participants, after explaining the objectives of the study, risks, and benefits involved. The ascent was obtained from all the students who participated in the study. The personal details of the students were kept confidential throughout the study. Health education was given to all students, parents and faculty members regarding lifestyle modifications and healthy nutrition. Individuals who are found to have overweight and obesity were provided with appropriate counseling services by trained clinicians. Any further investigations or treatment if required will be referred for an appropriate health care facility. Data collection tools: The data were collected by a structured proforma to collect information regarding demographics and lifestyle-related parameters, which can influence obesity. Study procedure: After obtaining the informed written consent and assent from all the study participants, the relevant information was collected and documented in structured proforma. Anthropometric parameters, including weight, height, were recorded using the standardized equipment. The weight was recorded by a digital beam balance and height was recorded by using a stadiometer.

Neck Circumference (NC) was measured using a flexible measuring tape immediately below the laryngeal prominence and perpendicular to the longitudinal axis of the neck so that the tape in front and back of the neck will be at the same level and the subject in Frankfurt plane. The measurement was taken while the child is standing and looking straight ahead with their shoulders relaxed and fallen. BP was recorded with child in sitting position using a sphygmomanometer with age specific appropriate cuffs.

Statistical methods: Hypertension, Neck circumference was considered as primary outcome variable: BMI was considered as the primary explanatory variable. Descriptive analysis: Descriptive analysis was carried out by mean.
and standard deviation for quantitative variables, frequency and proportion for categorical variables. Data was also represented using appropriate diagrams like bar diagram and pie diagram. All Quantitative variables were checked for normal distribution within each category of an explanatory variable by using visual inspection of histograms and normality Q-Q plots. Shapiro-wilk test was also conducted to assess normal distribution. Shapiro wilk test p value of >0.05 was considered as a normal distribution. For normally distributed Quantitative parameters, the mean values were compared between study groups using Independent sample t-test (2 groups) / ANOVA (>2 groups). Association between quantitative explanatory and outcome variables was assessed by calculating the person correlation coefficient, and the data was represented in a scatter diagram. ROC analysis: The utility of neck circumference in predicting BMI normal was assessed by Receiver Operative curve (ROC) analysis. The area under the ROC curve along with its 95% CI and p value are presented. P value < 0.05 was considered statistically significant. IBM SPSS version 22 was used for statistical analysis.

**DISCUSSION**

One of the most serious chronic health problems faced by children globally is obesity and has been described as the main cause for the deterioration of life expectancy during the 21st century. BMI is the most routinely used anthropometric measurement to record obesity. However, body fat distribution is not determined by BMI. Since upper body fat deposition is associated with an increased metabolic and cardiovascular risk, it is absolutely essential to determine fat accumulation in the upper body. Currently, Neck circumference has been shown as an easy and reliable substitute tool to Waist Circumference for determining upper body fat accumulation and distribution. Better inter- and intra-observer reliability, relative stability which is less affected by respiration and clothing are the advantages of measuring NC compared to WC. In the current study, NC has shown good predictive validity in predicting individuals with high BMI. And also determined reliable cutoff values of NC to diagnose obesity in both genders between the age group 6-16 years.

In this study, 940 participants were included, in which 470 (50%) participants were males, and 470 (50%) participants were female. The mean age was 11.03 ± 3.19, which is close to the median age of 11 years. As our study population were school children, the age ranged between 6 years to 16 years (95% CI 10.82 to 11.23). A greater proportion of the population, around 352 (37.4%) were between 6 to 9 years, 340 (36.2%) participants were aged >12 years, 248 (26.4%) participants were aged between 10 to 12 years.
The anthropometric measurements of the study participants were approximately normally distributed. The mean height was 138.78 ± 17.4, which is slightly lesser than the median height of 140cms. The mean weight was 38.29 ± 13.47, which is closer to the median weight of 38kgs. The average BMI was 19.07 ± 3.58 ranging between 10.70 to 29.60. The mean neck 64 circumference was 25.62 ± 4.59 in the study population, ranged between 16kg/m² to 34kg/m². The average systolic and diastolic blood pressure was 102.16± 7.64 and 59.31± 4.72, respectively in the study population.

Among the study population, 552 (58.7%) participants were normal, 219 (23.3%) participants were overweight, and 169 (18%) participants were obese. According to Atwa et al59 , in their study, 2346 (84.9%) were normal, and 416 (15.1%) were under the obese/overweight category. Similar results were obtained by Polat et al13 , in which 2040 (72·2 %) of the children had normal weight, 393 (13·9 %) were overweight, and 393 (13·9 %) were obese.

The prevalence of prehypertension in the present study was 29 (3.1%) whereas in a Turkish study conducted by Polat et al13 , a slightly higher prevalence of 7.9% was found. It is in line with the study conducted by Zhang et al14 , in Japan, where the prevalence of hypertension was found to be 7.2%.

The mean neck circumference of people with normal BP was 25.53 ± 4.57 cm, and it was 28.5 ± 4.32 cm in people with pre-hypertension in the present study. The difference in the neck circumference between BP centile was statistically significant (P Value 0.001). It is in accordance with the work of Guo et al15 , who examined whether there was an association between NC and high risk of change in BP, noted that, among eutrophic participants, elevated NC was significantly associated with a greater chance for change in BP (OR = 1.637; 95% CI 1.288-2.08).

He showed that NC could predict prehypertension in Chinese normal weight children and adolescents, but not in those overweight and obese. It is in contrast to the study conducted by Ferretti et al16 , who evaluated 917 adolescents showed that elevated blood pressure in adolescents is highly prevalent, even among healthy-weight individuals, which can be explained by style of teenage life, characterized by high consumption of foods high in salt, sugar and fat, in addition to physical inactivity, contributing to the increase in blood pressure and various metabolic disorders, even in apparently healthy individuals. Whereas Nafiu et al17 , in their study among American children confirmed that NC was consistently associated with elevated BP in both children with normal weight and those with high BMI (normal weight OR=1.78 (1.0–3.1), P=0.04); obese OR=2.44 (1.3–4.6), P=0.006))

Among the study population, there was a moderate positive correlation between BMI and neck circumference (r-value: 0.552, P value:<0.001) which is in accordance with the studies conducted by Santos et al18 , where the r value
is 0.604, (P value: <0.001). This is also similar to the study conducted by Nafiu et al\textsuperscript{19}, who observed a strong positive correlation between BMI and neck circumference.

The mean neck circumference had poor predictive validity in predicting BMI obese, as indicated by the area under the curve of 0.641 (95% CI 0.602 to 0.680, P value <0.001) in the present study. It is in contrast with the study conducted by Katz et al\textsuperscript{20}, who reported AUC of 0.884, which indicates a good predictive validity in determining obese individuals. Kelishadi et al\textsuperscript{65} have also reported NC to have an (AUC: 0.81 to 0.85, p<0.001) good predictive validity in predicting BMI obese. These differences may be attributed to differences in age groups and sample sizes.

TABLE 1: Age group, AUC, cut off, Sensitivity and Specificity values of NC measured in the present and different studies.

<table>
<thead>
<tr>
<th>Current study</th>
<th>Age group</th>
<th>AUC</th>
<th>Optimal values (Neck circumference)</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>6 to 12 years</td>
<td>0.653</td>
<td>26</td>
<td>53</td>
<td>50</td>
</tr>
<tr>
<td>Female</td>
<td>6 to 12 years</td>
<td>0.589</td>
<td>25.25</td>
<td>47.4</td>
<td>48.0</td>
</tr>
<tr>
<td>Male</td>
<td>&gt;12 years</td>
<td>0.831</td>
<td>28.75</td>
<td>82.4</td>
<td>65.3</td>
</tr>
<tr>
<td>Female</td>
<td>&gt;12 years</td>
<td>0.841</td>
<td>27.25</td>
<td>75</td>
<td>75.9</td>
</tr>
<tr>
<td>Taheri et al Males</td>
<td>6-17 years</td>
<td>0.884</td>
<td>27.5-38.3</td>
<td>60-88.9</td>
<td>71.4-88.5</td>
</tr>
<tr>
<td>Females</td>
<td>6-17 years</td>
<td>0.785</td>
<td>26.7-33.4</td>
<td>71.4-78.5</td>
<td>67.7-82.8</td>
</tr>
<tr>
<td>Nafiu et al\textsuperscript{19}(males)</td>
<td>6-18 years</td>
<td>0.589</td>
<td>28.5-39.0</td>
<td>60-100</td>
<td>67.9-100</td>
</tr>
<tr>
<td>Females</td>
<td>6-18 years</td>
<td>0.653</td>
<td>27.0-34.6</td>
<td>60-78.5</td>
<td>55.6-100</td>
</tr>
<tr>
<td>Hatipoglu et al\textsuperscript{21} males</td>
<td>6-18 years</td>
<td>0.826</td>
<td>28-38</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Females</td>
<td>6-18 years</td>
<td>0.831</td>
<td>27-34.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lou et al\textsuperscript{22} males</td>
<td>7-12 years</td>
<td>0.764</td>
<td>27.4-31.3</td>
<td>75.5-86.7</td>
<td>73.9-91.7</td>
</tr>
<tr>
<td>Females</td>
<td>7-12 years</td>
<td>0.850</td>
<td>26.3-31.4</td>
<td>80-92.5</td>
<td>74.7-93.3</td>
</tr>
<tr>
<td>Atwa et al\textsuperscript{23} males</td>
<td>12-15 years</td>
<td>0.898</td>
<td>29.3-31.7</td>
<td>91-96</td>
<td>55-91</td>
</tr>
<tr>
<td>Females</td>
<td>12-15 years</td>
<td>0.912</td>
<td>28.6-31.4</td>
<td>90-96</td>
<td>56-83</td>
</tr>
</tbody>
</table>

This study demonstrates the importance of NC in adolescents. Being low cost, simple, and easily available, this method could be a screening tool to predict obese individuals. It has highly significant positive correlations with body weight. So, NC can be considered as a good indicator and predictor for...
SUMMARY

In this study, 940 participants were included, in which 470 (50%) participants were males, and 470 (50%) participants were female. The mean age was 11.03 ± 3.19. Around 352 (37.4%) were between 6 to 9 years, 340 (36.2%) participants were aged >12 years, 248 (26.4%) participants were aged between 10 to 12 years.

The mean height was 138.78 ± 17.4 in the study population. The mean weight was 38.29 ± 13.47 in the study population. The mean BMI was 19.07 ± 3.58. The mean neck circumference was 25.62 ± 4.59. The average systolic and diastolic blood pressure was 102.16 ± 7.64 and 59.31 ± 4.72, respectively.

Among the study population, 552 (58.7%) participants were normal, 219 (23.3%) participants were overweight, and 169 (18%) participants were obese. The prevalence of prehypertension in the present study was 29 (3.1%). The mean neck circumference of people with normal BP was 25.53 ± 4.57 cm, and it was 28.5 ± 4.32 cm in people with prehypertension in the present study. The difference in the neck circumference between BP centile was statistically significant (P Value 0.001).

A moderate positive correlation between BMI and neck circumference (r-value: 0.552, P value: <0.001) in the present study. The mean neck circumference had poor predictive validity in predicting BMI obese, as indicated by the area under the curve of 0.641 (95% CI 0.602 to 0.680, P value <0.001) in the present study.

Among the males, the mean neck circumference with normal BMI was 25.55 ± 4.58 cm, and it was 26.94 ± 5.01 cm in obese. The difference in the neck circumference between BMI classification was statistically significant (P Value 0.002). Among the females, the mean neck circumference with normal BMI was 24.64 ± 3.87 cm, and 25.7 ± 4.85 cm in obese. It was statistically significant (P Value 0.013).

Among the 6 to 9 years age group, the mean neck circumference with normal BMI was 19.7 ± 3.61 cm, 22.56 ± 4.64 cm in obese. Among the 10 to 12 years, the mean neck circumference with normal BMI was 27.26 ± 0.97 cm, 29.08 ± 1.97 cm in obese and was statistically significant (P Value <0.001). Among the >12 years age group in the study population, the mean neck circumference with normal BMI was 27.3 ± 1.64 cm, 30.27 ±
2.24 cm in obese.

In the present study Area Under the Curve values of 0.653 (95% CI 0.590 to 0.716, P value <0.001) and 0.589 (95% CI 0.515 to 0.664, P value 0.013) were observed for males and females, respectively for age group 6 to 12 years. Among more than 12 years old, the mean neck circumference had good predictive validity in predicting BMI obese in both males and females, with Area Under the Curve of 0.831 (95% CI 0.762 to 0.901, P value <0.001) and of 0.841 (95% CI 0.769 to 0.913, P value <0.001) for males and females, respectively.

CONCLUSION

The prevalence of obesity is 18% and this study demonstrates the importance of NC in adolescents. Being low cost, simple, and easily available, this method could be a screening tool to predict obese individuals. It has highly significant positive correlations with body weight. So, NC can be considered as a good indicator and predictor for obesity and hypertension.

There is paucity of studies in India regarding NC and obesity in children, further studies are recommended for NC to be a useful screening measure for identifying overweight or obese children and adolescents at the population level. Prediction of obstructive sleep apnea, especially in obese children, can be evaluated with NC. Additional studies to evaluate the usefulness of NC as an index of adiposity in younger children are warranted. The importance of changing the lifestyle of these children should be emphasised, especially with regard to eating habits and the practice of regular physical activity.

REFERENCES


