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Original Research Article

To Determine the Accuracy of Neck Circumference and Waist Circumference as a Screening Tool for Overweight and Obesity in Children Aged Between 6-15 Years- A Prospective Cross Sectional Observational Study

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Conflict of interest: Nil

Abstract

Background: Obesity in children is a significant public health concern globally, contributing to various long-term health complications such as cardiovascular diseases, type 2 diabetes, and psychosocial issues. Accurate and easily accessible screening tools are necessary to identify children at risk of obesity early. Traditionally, Body Mass Index (BMI) has been used to assess overweight and obesity in children. However, due to its limitations, such as not accounting for fat distribution, central obesity, alternative anthropometric measurements like neck circumference (NC) and waist circumference (WC) have gained attention as potential screening tools, for better predictor of cardiovascular risk in future.

Objectives: Primary Objective: To determine the accuracy of Neck circumference (NC) and Waist circumference (WC) as a measure for screening overweight and obesity in children aged 6-15yrs, by correlating the results with Body mass index (BMI).

Secondary Objective: To estimate the prevalence of overweight and obesity in school going children aged 6-15 years in B.G. Nagara, Rural Mandya.

Methods: An Observational cross-sectional study was conducted among 804 school going children aged between 6 years– 15 years from schools in Nagamangala taluk, Mandya district. After obtaining Ethical Committee clearance and permission from school principal, data was collected after from students, in the form of self-formulated questionnaire, which included anthropometric measurements. Data was analysed using licensed version of SPSS 30. The description of data is in the form of mean (±) SD for quantitative data and frequency and proportion for qualitative data. Student-t test was used to compare continuous variables and $\chi 2$ (Chi-square) test was used to compare categorical variables. P value <0.05 was considered statistically significant.

Results: The area under the ROC curve (AUC) was 0.841, for neck circumference and 0.834 for waist circumference indicating excellent discriminatory ability of neck and waist circumference in identifying obesity. The prevalence of overweight and obesity combined was significantly high, with 29.2% categorized as overweight and 24.1% as obese, while 46.6% had a normal BMI and 3.4% underweight. The mean BMI of the study population was 19.74 kg/m² (SD ± 2.72).

Interpretation & Conclusion: The present study provides comprehensive insights into the role of neck circumference (NC) and waist circumference (WC) as screening tools for overweight and obesity among children aged 6-15 years. Neck circumference and waist circumference can serve as reliable anthropometric markers in conjunction with BMI to screen for obesity. Increased Neck circumference and waist circumference are associated with obesity-related risks such as cardiovascular diseases, metabolic syndrome, and sleep apnea. BMI, NC, and WC together could improve obesity assessment, especially in predicting metabolic risks.

The high prevalence of overweight and obesity identified in this study further underscores the urgent need for early detection and intervention.

Keywords: Obesity, Body Mass Index, Neck Circumference, Waist circumference.

Introduction

As seen by the high frequency of stunting, anaemia, and iron and zinc shortages, the world is undergoing a rapid epidemiological and nutritional change characterised by persistent nutritional deficits [1].

With rising rates in both high-income and low- and middle-income countries (LMICs), childhood and adolescent obesity has emerged as a global health concern [2]. Childhood obesity frequently carries over into adulthood and is associated with a higher chance of early mortality as well as a higher risk of cardio-metabolic and psychological health problems [3-5].

The state of abnormal or excessive fat build-up in adipose tissue, to the point that health may be compromised, is commonly referred to as obesity [6]. Simple anthropometric measurements are frequently employed as screening instruments for epidemiological investigations and standard clinical evaluations6. Children and adolescents' body mass is indirectly indicated by their BMI (weight/height^2; kg/m2), which should be compared to the population growth reference that has been corrected for age and sex [6].

Many children and their families were probably negatively impacted psychologically by the protracted stress of the epidemic and quarantine, which may have led to stress-related eating patterns and, eventually, childhood obesity [7-9].

A cost-effective method of measuring body fat is the body mass index (BMI), which is determined for children aged 2 to 12 using a formula based on height and weight [10-12]. Although there are more sophisticated methods for measuring body fat directly, they are costly and difficult to use [13]. These techniques include air displacement plethysmography, hydro-densitometry, dual-energy X-ray absorptiometry (DEXA), bioelectrical impedance, and skin fold thickness assessment using a caliper [13]. It has been demonstrated that body fat levels and potential health hazards are correlated with BMI, which offers a helpful indirect measure of body fat in healthy children [12]. In contrast to adults, children's BMI is represented by Z-scores or percentiles, which change according to age and sex [12]. The World Health Organisation (WHO) suggests defining those who are at risk of being overweight, overweight, and obese, respectively, using BMI Z-score cut-off points of >1.0, >2.0, and >3.012 [12].

Obesity is defined as having a BMI above the 95th percentile, and overweight is defined as having a BMI between the 85th and 94th percentiles [12]. While BMI percentiles are better suited for clinical contexts, BMI Z-scores are advised for usage in research to prevent these errors [14].

A study from India defines overweight as BMI between the 85th and 94th percentiles, and obesity as BMI at or above the 95th percentile [15]. Neck circumference (NC) and waist circumference (WC) have been suggested as potential indicators of upper-body and abdominal fat distribution, respectively [16]. These measurements are simple to perform, non-invasive, and cost-effective, making them ideal for large-scale screenings in settings such as schools and community health programs [16]. Recent research has investigated the effectiveness of Neck Circumference and Waist Circumference as screening tools for overweight and obesity in children, focusing on validating their use and determining appropriate cut-off values for different age and sex groups [16].

For instance, a cross-sectional study by Sreelatha and Chinchilu et al [16]. (2021) identified a strong positive correlation between neck circumference (NC) and both BMI and waist circumference (WC) [16]. The study suggested age- and gender-specific cut-off values for neck circumference (NC) to identify overweight and obesity, with sensitivities ranging from 87.5% to 100% and specificities between 52.2% and 88.9% [16]. Similarly, research by Carvalho et al [17], (2023) established NC cut-off points of 44.0 cm for males and 40.0 cm for females, with the areas under the ROC curve (AUC) showing moderate predictive ability for obesity and a high risk of cardiovascular issues [17]. Additionally, a study by Dongre et al [18]. (2024) found positive correlations between neck circumference (NC) and other anthropometric measures, including waist circumference (WC), hip circumference, and BMI, indicating that NC is a reliable tool for assessing childhood obesity [18]. These studies underscore potential of Neck Circumference and Waist Circumference as practical screening tools for detecting overweight and obesity early in children. Implementing such measures can facilitate timely interventions aimed at preventing the progression of obesity and mitigating associated health risks [16]. However, it is essential to establish standardized measurement protocols and age- and sex-specific reference values to enhance the accuracy and applicability of these tools across diverse populations. Hence the current study is undertaken for the same [16].

Vicious cycle of o besity in school children

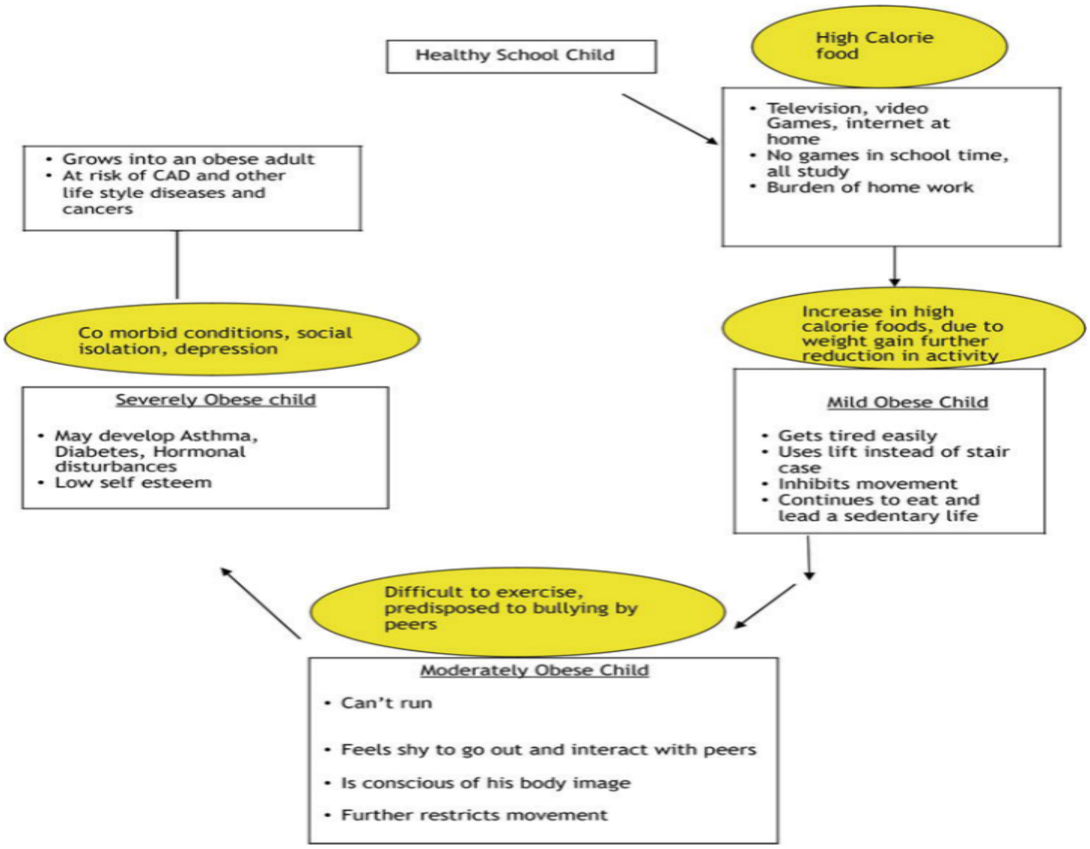


Figure 1:

Aims and Objective

- To determine the accuracy of Neck circumference (NC) and Waist circumference (WC) as a measure for screening overweight and obesity in children (6-15yrs), by correlating the results with Body mass index (BMI).
- To estimate the prevalence of overweight and obesity in school going children aged 6- 15 years in B.G. Nagara, Rural Mandya.

Materials and Methods

Study Design: Observational study**,** Cross Sectional

Duration of Study: 18months. [JULY2023-JAN 2025]

Study Population: Schools with the students aged 6-15 years in rural B.G Nagara, Mandya district.

Study Area: Rural B.G. Nagara, Mandya district.

Sampling Methods: Convenience Sampling

Sample Size: Cochran formula is used for sample size estimation.

n=4pq/d2
n=4x33.2x66.8/11.02

n=**804**

Where,

n=sample size

p =33.2 prevalence of overweight and obesity in school going children based on previous recent study.
q=100-p

d=allowable error (10% of p) = 11.02.

Inclusion Criteria:

- Children between 6-15 years

Exclusion Criteria:

- Children whose parents or guardian did not give consent to participate in study
- Children having any chronic illness
  - Endocrine disorders [Thyroid Disorders, Cushing's syndrome etc.]
  - Metabolic disorders
  - -Neurological/Genetic disorders [Cerebral palsy, neuromuscular disorders, Muscular dystrophy.]
- Children with Neck swellings or cysts or spinal deformities

Method of Data Collection: After taking Ethical Committee clearance, the study was conducted in school going children of age 6-15 years, studying in B.G. Nagara, rural Mandya, and Karnataka, India. Schools were selected according to convenience. Prior consent was taken from

Principals, parents and students of the school for participation in our study. The students were given a self-formulated questionnaire which consisted of questions to be answered by the student. The questionnaire will be explained to the students beforehand. It includes demographic description, annual income, family history, dietary habits, activity pattern, screen time, and anthropometric measurements like, waist circumference, neck circumference, weight and height measurement for BMI calculation.

Height was measured barefoot, to the nearest of 0.1 cm using a standard calibrated bar. The student stood straight with heels, buttocks and back touching the vertical limb of the wall and stretching upward to the fullest extent with arms hanging on the sides. The head was aligned such that the lower rim of the orbit and the auditory canal will be in the horizontal plane (Frankfurt place).

Weight was measured without any footwear with minimal clothing (school uniforms) to the nearest of 0.1kg using a standard portable weighing machine and the scale was zeroed before each session, weight was recorded in kilograms[19].

Neck circumference was measured immediately below the thyroid cartilage (Adam's apple) and perpendicular to the longitudinal axis of the neck (such that the measuring tape in front and back of the neck was at the same height). A flexible measuring tape was used to take the measurement while the child is standing and looking straight ahead with their shoulders relaxed and fallen.

Waist circumference was measured while the child was standing at the end of a normal expiration at the midpoint between the lower edge of the last rib, and the upper edge of the iliac crest, using a fabric measuring tape.

BMI was calculated for all children using the standard formula, and BMI percentiles were determined for each individual with respect to age and gender. Accordingly, children with a BMI percentile BMI was used to assess the obesity based on the BMI charts developed by IAP percentile charts 2015, it was considered as a standard for the present study.[20]

A child was considered to be,

- UNDERWEIGHT: BMI <5th centile.
- NORMAL: BMI 5th -85th centile.
- OVERWEIGHT: BMI ≥23rd adult equivalent cut off
- OBESE: BMI ≥27th adult equivalent cut off

Statistical Methods

Data was collected and compiled in MS Excel.

Statistical analysis was performed using SPSS for windows version 30.0.

The description of data is in the form of mean (±) SD for quantitative data and frequency and proportion for qualitative data.

Student t test was used to compare continuous variables and $\chi 2$ (Chi-square) test was used to compare categorical variables.

P value <0.05 was considered statistically significant**.**

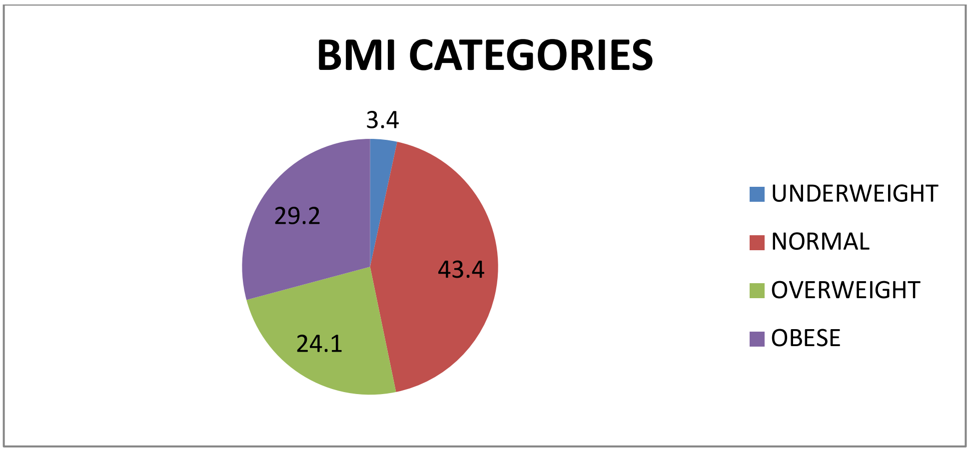
Pearson's correlation co-efficient was done to asses correlation between the variables.

The Receiver Operating Characteristic analysis was conducted to asses sensitivity and specificity of the variables.

Results

Graph 1: Bmi Category

The prevalence of overweight and obesity combined was significantly high, with 29.2% categorized as overweight and 24.1% as obese, while 3.2% underweight and 43.4% had a normal BMI. The mean BMI of the study population was 19.74 kg/m² (SD ± 2.72).

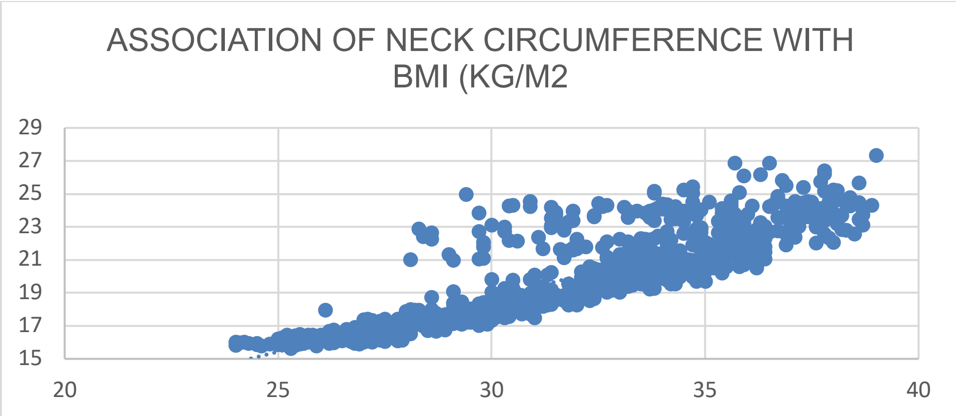


Graph 1: Bmi Category

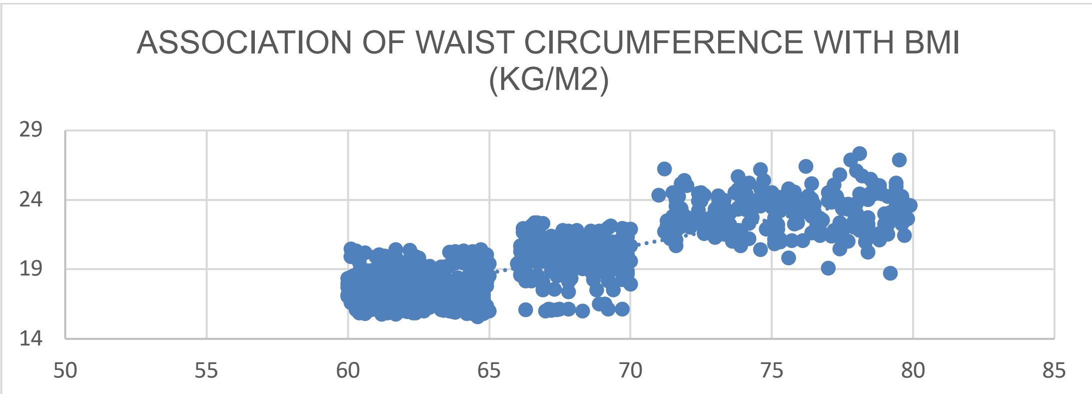
Table 1: Correlation of NC and WC with Bmi

Association With BMI	Pearson Correlation	P value
Neck Circumference (CM)	0.855	<0.001
Waist Circumference (CM)	0.834	<0.001

Pearson correlation coefficient (r = 0.855) indicates a very strong positive correlation between neck circumference and BMI. This suggests that as BMI increases, neck circumference also increases significantly. The p-values are highly significant, confirming that the observed correlations are not due to chance. The correlation between waist circumference and BMI (r = 0.834) is also strongly positive, implying that higher BMI is associated with greater waist circumference. The p-values are highly significant, confirming that the observed correlations are not due to chance. Neck circumference and waist circumference can serve as reliable anthropometric markers for BMI. Increased NC and WC are associated with obesity-related risks such as cardiovascular diseases, metabolic syndrome, and sleep apnea. BMI, NC, and WC together could improve obesity assessment, especially in predicting metabolic risks.



Graph 2: Association of Neck Circumference with BMI



Graph 3: Association of Waist Circumference with BMI

Table 2: Sensitivity and Specificity Neck Circumference

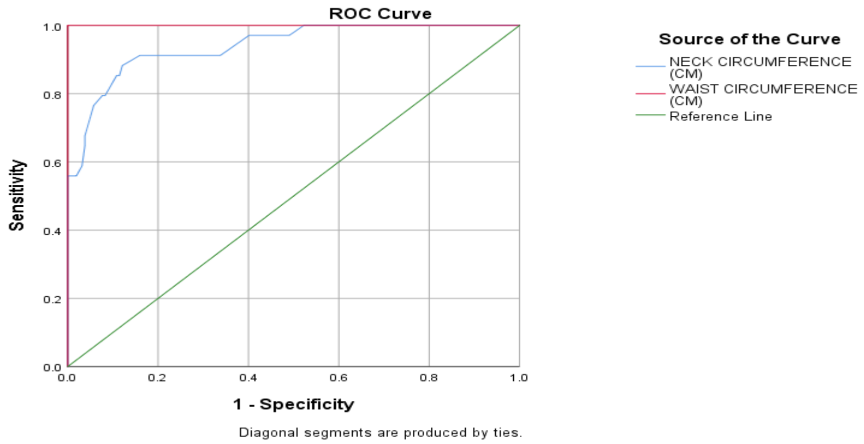
NC	Area	Cutoff	Sensitivity	Specificity	P value	Lower	Upper
<10Y males	.940	28.150	.971	.490	<0.001	.897	.983
<10Y females	.942	28.350	.970	.310	<0.001	.905	.979
>10Y males	.871	32.550	.990	.545	<0.001	.829	.913
>10Y females	.889	33.300	.972	.404	<0.001	.846	.931

The Receiver Operating Characteristic (ROC) analysis was conducted to assess the predictive ability of neck circumference (NC) and waist circumference (WC) as indicators of obesity or metabolic risk in children and adolescents. The area under the curve (AUC) values for NC were high, indicating that it is a reasonably effective screening tool, particularly in older males (AUC = 0.871) and females (AUC = 0.889). The cutoff values for NC were 28.15 cm for males and 28.35 cm for females in the <10 years group, with higher cutoffs of 32.55 cm and 33.3 cm, respectively, for those aged >10 years. While sensitivity values remained high (above 0.97 across all groups), specificity was relatively lower, particularly in younger females (0.310), indicating that while NC can reliably identify children at risk, it may also lead to some false positives.

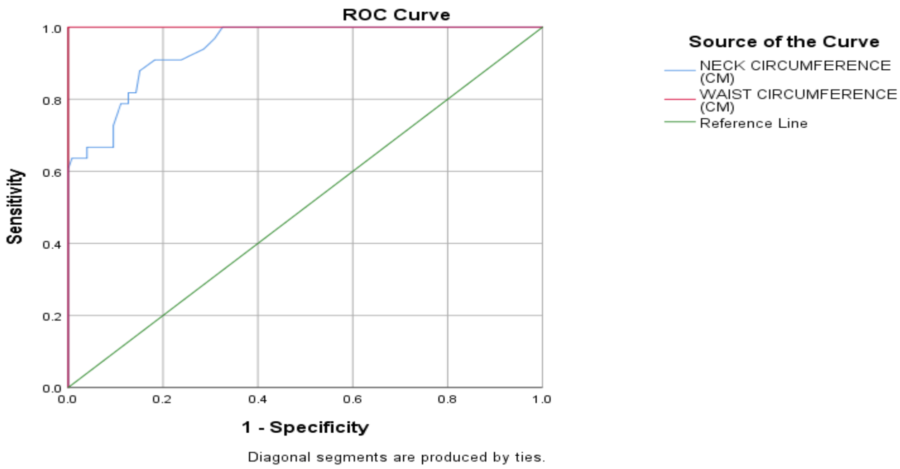
Table 3: Sensitivity and Specificity Neck Circumference

WC	Area	Cutoff	Sensitivity	Specificity	P value	Lower	Upper
<10Y males	1.000	60.050	1.000	.987	**<0.001**	1.000	1.000
<10Y females	1.000	60.050	1.000	.992	**<0.001**	1.000	1.000
>10Y males	1.000	62.850	1.000	.699	**<0.001**	1.000	1.000
>10Y females	1.000	62.850	1.000	.757	**<0.001**	1.000	1.000

Waist circumference (WC) had an AUC of 1.000 across all age and gender groups, demonstrating perfect diagnostic accuracy. The WC cutoff values were 60.05 cm for both males and females under 10 years and 62.85 cm for those over 10 years. Sensitivity and specificity were 100% in all cases, confirming that WC is an ideal and highly reliable metric for assessing obesity-related risks.



Graph 4: Roc for Boys:



Graph 5: Roc for Girl:

Discussion

About 70% of premature deaths are caused by non-communicable diseases (NCDs), which are the leading cause of mortality and premature disability globally. These illnesses include cancer, heart disease, and diabetes mellitus. Depending on the severity of the condition and any underlying problems, obesity is one of the primary risk factors for non-communicable diseases (NCDs) and is associated with a shorter life expectancy of five to twenty years. The World Health Organization defines obesity as an excessive accumulation of fat that may have detrimental health effects, and it is diagnosed at a BMI of 30 kg/m^2 [21-23].

A greater metabolic hazard can be predicted by neck circumference (NC), a measure of the distribution of subcutaneous adipose tissue in the upper torso. Even after controlling for visceral adipose tissue (VAT) and body mass index (BMI), there is still a correlation between neck circumference and cardiovascular disease risk variables. These results suggest that fat in the upper body could be a unique, harmful fat reservoir [23]. According to the well-known Framingham Heart Study, neck circumference is a measure of central obesity since it correlates with visceral adiposity and BMI on its own [24].

Importantly, the World Obesity Federation and other organizations, including the American and Canadian Medical Associations, have recognized obesity as a chronic, progressive disease, setting it apart from being just a risk factor for other illnesses. Obesity greatly increases the risk of metabolic diseases like type 2 diabetes mellitus and fatty liver disease, cardiovascular diseases like hypertension, myocardial infarction, and stroke, musculoskeletal diseases like osteoarthritis, cancers like breast, ovarian, prostate, liver, kidney, and colon, and depression. Obesity can also lead to a lower quality of life, unemployment, reduced productivity, and social disadvantages. For example, one of the primary causes of early retirement and disability is osteoarthritis, which is frequently caused by obesity [25-27].

The present study provides comprehensive insights into the role of neck circumference (NC) and waist circumference (WC) as screening tools for overweight and obesity among children aged 6-15 years. The results highlight significant findings related to demographic distribution, obesity prevalence, and the predictive accuracy of NC and WC in identifying children at risk. These findings have crucial implications for the early detection and management of childhood obesity, especially in rural settings where traditional BMI-based assessments may be challenging to implement [26,27].

The present study included a total of 804 children, with a nearly balanced gender distribution (45.3% female and 54.7% male). Our participants were categorized into two broad age groups: 5-10 years (43.2%) and 11-15 years (56.8%), with a mean age of 11.06 ± 2.64 years. Similar to our study, Ashok et al. [28] focused on a sample of 360 participants aged 13–16 years, with a mean age of 14.38 ± 0.85 years and 54.4% as males in their study.

In another study by Malini et al [29], they included a larger sample of 1,139 children, where 45.22% were boys and 54.78% were girls, and their age group under 12 years old were 21.2% and those between the ages of 12 and 17 were 78.7% respectively. In another study by Patnaik et al. [30], they conducted on a larger sample of 1800 adolescents aged 10–16 years, with a mean age of 13.0 ± 1.4 years. The current study recorded the mean anthropometric values for various parameters, including neck circumference (31.59 ± 3.56 cm), waist circumference (66.82 ± 2.66 cm), height (136.95 ± 11.19 cm), and weight (37.76 ± 9.84 kg). These measurements provided a baseline for assessing the correlation between NC, WC, and BMI. Similarly, according to Malini et al [29], normal-weight females had mean NC values of 27.8±2.39 cm while boys had mean NC values of 30±3.38 cm.

Regarding the NC, the results of research that utilized it as a parameter to evaluate children's central adiposity suggest that it could be a helpful screening tool to detect overweight or obesity, despite the paucity of studies in the literature that embraced this measurement. When age and gender-adjusted references are provided, it may also be helpful in diagnosing children who are at risk for high adiposity, a significant predictor of cardiovascular health issues [31-33].

A detailed analysis of NC and WC in our study demonstrated strong associations with BMI, reinforcing their potential as reliable screening tools. NC showed a steady increase with age, ranging from 26.4 cm at age 6 to 36.33 cm at age 15, with a highly significant p-value (<0.001). Similarly, BMI increased progressively with age, from a mean of 17.12 kg/m² at age 6 to 22.35 kg/m² at age 15, also with a p-value of <0.001 in this study. These findings indicate a consistent relationship between NC, age, and BMI, suggesting that NC can serve as an age-adjusted parameter for obesity risk assessment. Similar to our study, Ferretti R de L et al.'s study [34] of children and adolescents revealed a strong relationship between body mass index and neck circumference in both genders (31.62 ±4.54 kg/m2, p <0.001).In concordance to our study, according to the Malini et al. [29] research, children who were overweight or obese had considerably higher NC than children with normal BMI (p<0.001) and NC rose to 33.1±2.90 cm for boys and 30.1±2.25 cm for girls who were overweight, and it further climbed to 34±4.51 cm for boys and 31.7±3.44 cm for girls who were obese in their study.

In the present study, WC exhibited an even stronger correlation with BMI, with statistically significant differences across BMI categories. Children with normal BMI had a mean WC of 62.42 cm, while those classified as overweight had a mean WC of 68.01 cm, and obese children had a mean WC of 75.53 cm.

This trend further establishes WC as a highly effective predictor of obesity, demonstrating a clear gradient between increasing WC and higher BMI. Similar to our study, Patnaik et al. [30] found that the area under the curve for both waist and neck circumferences in both boys and girls was greater than 80%, suggesting that it was accurate in identifying teenagers with high BMI. Furthermore, in both boys (0.866 vs. 0.823) and girls (0.850 vs. 0.816), the AUC for waist circumference was greater than that for neck circumference, suggesting that waist circumference might be a more accurate indicator of adolescent obesity.

The predictive capability of NC was assessed using Receiver Operating Characteristic (ROC) curve analysis in this study. The Area under the Curve (AUC) for NC ranged from 0.834 to 0.848 across different BMI categories, suggesting a strong discriminatory ability. AUC values between 0.8 and 0.9 in the present study, indicating high diagnostic accuracy, meaning NC can effectively distinguish between normal-weight and overweight/obese children. In concordance to our study, Malini et al. [29] found an association between NC and BMI of r = 0.84 for males and r = 0.75 for girls ($p<0.001$) in children under the age of twelve, and r = 0.73 for boys and r = 0.84 for girls ($p<0.001$) in the group of children aged twelve to seventeen. Furthermore, in both age groups, a substantial association between NC and WC was noted in their study, suggesting that NC may be used as a screening tool for obesity.

Also, Malini et al. [29] established NC threshold values for obesity screening that were specific to age and gender. The NC cutoff was 26.5 cm (sensitivity: 83.3%, specificity: 71.7%) for boys aged 6–11 years and 26.5 cm (sensitivity: 81.4%, specificity: 70.5%) for girls in the same age range. The cutoff was 34 cm (sensitivity: 83.3%, specificity: 75.6%) for boys aged 12–17 and 31 cm (sensitivity: 94.3%, specificity: 83.2%) for girls. ROC analysis was used to validate these cutoff values, and the results showed high predictive performance with AUC values ranging from 0.82 to 0.95.

Additionally, Yashoda et al 35 revealed NC cutoff values in adolescents of 32 cm for boys and 30 cm for girls, with a sensitivity of 81.8% and 84.8%, respectively. In contrast, Patnaik et al.'s study [30] found that the NC cutoff values were 30.75 cm for boys and 29.75 cm for girls, with a sensitivity of 79.2% and 72.5%, respectively.

The current study results show that NC, while not perfect, is a good indicator of obesity and could be used as a simple screening tool, particularly in resource-limited settings where BMI measurements may not always be feasible.

Among the two anthropometric measures analyzed in our study, WC emerged as the most accurate predictor of obesity. The AUC for WC was found to be 1.00 across all BMI categories, indicating perfect sensitivity and specificity. An AUC of 1.00 is the highest possible value in diagnostic testing, implying that WC can identify obesity with absolute precision, without any false positives or false negatives.

Moreover, the study's findings reinforce the need for incorporating simple, cost-effective, and reliable anthropometric measurements into routine pediatric screenings. While BMI remains the gold standard for obesity classification, its calculation requires precise measurements and may not always be practical in field settings. In contrast, NC and WC offer quick and efficient alternatives that can be easily implemented by healthcare providers, school authorities, and public health professionals [36-41].

Limitations

Our study had some limitations.

- First, the sample was region-specific, which may restrict the generalizability of the results to other populations with different ethnic, genetic, or lifestyle factors.
- Secondly, as convenience sampling method was used, selection bias could not be prevented.

Conclusion

Our study highlights robust evidence supporting the use of neck circumference (NC) and waist circumference (WC) as effective screening tools for childhood obesity. While Neck Circumference demonstrated a strong correlation with BMI and a high predictive accuracy, Waist Circumference emerged as the superior predictor. These findings suggest that both Neck Circumference and Waist Circumference can be used as a primary screening measure for obesity in children, particularly in community and school health programs.

The high prevalence of overweight being 29.2% and obesity being 24.1%, identified in this study further underscores the urgent need for early detection and intervention. Given the rising rates of childhood obesity and its associated health risks, implementing simple yet reliable screening methods like Waist circumference & Neck Circumference can significantly enhance the effectiveness of obesity prevention strategies.

Recommendation

On the background of higher prevalence of obesity in school children formulation and implementation of intervention (short and long term) measures is recommended.

Policymakers and healthcare providers should consider incorporating Waist Circumference and Neck Circumference assessments into routine pediatric evaluations to improve early identification and management of obesity in children.

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