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Neck Circumference as a Predictor of Malnutrition among School Age Children in Bharatpur, Nepal: A Community Based Study

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Abstract

Background

Malnutrition, including both undernutrition and obesity, remains a major public health concern among children in developing countries such as Nepal. Conventional anthropometric measures like BMI require standardized equipment and trained personnel, limiting their feasibility in large-scale screenings. Neck circumference (NC) has emerged as a simple and practical alternative for identifying adiposity in children. This study aimed to examine the association between NC and established anthropometric indicators and to determine optimal NC cutoff values for identifying overweight among school-aged children.

Methods

A community-based descriptive cross-sectional study was conducted from July to October 2025 among 300 apparently healthy children aged 6–11 years in Ward No. 16, Bharatpur Metropolitan City, Nepal. Sociodemographic data were collected using structured interviews. Anthropometric measurements including height, weight, NC, waist circumference (WC), and hip circumference (HC) were obtained using standardized procedures. BMI-for-age classifications were based on WHO AnthroPlus growth references. Pearson correlation, chi-square tests, and receiver operating characteristic (ROC) curve analyses were performed using SPSS version 16. Statistical significance was set at $p < 0.05$.

Results

Among the 300 children, 48.3% had normal BMI-for-age, 41.3% were underweight, and 10.3% were overweight. NC showed significant associations with BMI-for-age, height-for-age, and weight-for-age ($p < 0.001$), but not with waist–hip ratio ($p = 0.26$). Pearson correlation analysis demonstrated strong positive correlations between NC and weight ($r = 0.792$), waist circumference ($r = 0.797$), BMI ($r = 0.723$), hip circumference ($r = 0.734$), and height ($r = 0.639$) ($p < 0.001$ for all). ROC curve analysis indicated excellent diagnostic accuracy of NC for identifying overweight. The optimal cutoff values were 27.75 cm for boys (AUC = 0.884; sensitivity = 88.9%; specificity = 66.2%) and 26.75 cm for girls (AUC = 0.904; sensitivity = 100%; specificity = 69.4%). The overall cutoff value was 27.25 cm (AUC = 0.883; sensitivity = 80.6%; specificity = 74.3%).

Conclusions

Neck circumference is significantly correlated with established anthropometric indicators and demonstrates high diagnostic accuracy for identifying overweight and obesity among school-aged children. NC measurement is a simple, reliable, and cost-effective screening tool that may be particularly useful in school-based and resource-limited settings.

Introduction

Malnutrition, encompassing both undernutrition and obesity, remains a pressing public health issue among children, particularly in developing countries like Nepal, despite ongoing global efforts to improve child nutrition. Nutritional status is a critical health indicator for school-age children experiencing rapid physical and cognitive development. Nepal's 2015 Constitution establishes food sovereignty as a fundamental right(1), yet over one-third of children under five still suffer from malnutrition (2).

While traditional anthropometric indicators like BMI and weight/height ratios are commonly used for nutritional assessment, they present challenges including measurement inconsistencies and requirements for trained personnel and specialized equipment. Neck circumference (NC) has emerged as a promising alternative that

reflects upper body subcutaneous fat distribution, that is less influenced by daily fluctuations than conventional measures and has demonstrated associations with metabolic risks factors making it a convenient and reliable tool for identifying overweight and obesity in children(3, 4).

Although pediatric NC research began in 2010 and international studies have demonstrated its potential for identifying overweight, obesity, and metabolic syndrome, widespread clinical adoption remains limited due to the absence of universally accepted cut-off values for children(5). Therefore, this study aimed to explore the relationship between NC and established nutritional indicators, and determine appropriate NC cutoff values for identifying malnutrition, ultimately contributing to the development of a simple, cost-effective approach to early nutritional screening in children.

Materials and Methods

A community-based, descriptive cross-sectional study was conducted from July to October 2025 in Ward No. 16, Bharatpur Metropolitan City, Chitwan District, Nepal. The study population comprised apparently healthy school-age children aged 6 to 11 years residing within the designated ward boundaries whose parents or legal guardians provided written informed consent.

Considering prevalence of 25.7%(5), level of significance at 95% and allowable error at 5% a total of 300 children were selected as sample for this study. Participants were recruited through systematic household enumeration within the study area.

Sociodemographic information was obtained through face-to-face interviews using a pre-tested, structured questionnaire administered to parents or guardians. Anthropometric data of children, including height, weight, neck circumference, waist circumference, and hip circumference were recorded by a single investigator eliminating inter-observer bias. Data were collected using weighing machine, stadiometer and flexible measuring tape. For height measurement, each participant was instructed to stand barefoot and head held in Frankfurt horizontal plane to the nearest 0.1 cm. Weight was measured without shoes or extra clothing by using a calibrated electronic weighing scale, to the nearest 0.1 kg.

NC was measured between the mid cervical spine and mid anterior neck, using a flexible measuring tape with the child in the standing position, head held erect and eyes facing forwards and neck in the horizontal plane at the level of most prominent position, the thyroid cartilage. WC was measured by using flexible measuring tape to the nearest 0.1 cm with the child standing, and at the end of normal expiration at a point midway between the inferior margin of the lowest rib and the iliac crest. HC was measured at the maximum circumference around the buttocks.

Waist-To-Hip Ratio (WHR) was calculated by dividing WC by HC. BMI kg/m2 was calculated using WHO Anthroplus and interpreted according to WHO guidelines. Height for age was categorized as stunted, normal, and tall; weight for age was categorized as underweight, normal, and overweight. BMI for age and sex percentile growth curves were used to classify the children and was defined as underweight (less than 5th percentile), normal weight (5th percentile to less than the 85th percentile), and overweight (more than 85th percentile).

For the statistical analysis, Statistical Package for the Social Sciences (SPSS) version 16 was used. Data were expressed in terms of mean and standard deviation. Pearson correlation coefficient was applied to test correlation between the NC and other continuous variables like Age, height, weight, BMI, WC, HC and WHR. Receiver operating characteristic (ROC) analyses was used to find out the ability of NC to identify correctly children with high BMI, and to determine the best NC cut-off point for identifying children as overweight. A test with an area under the curve (AUC) 0.85 is considered an accurate test(6). The best cutoff values were established for male and female children separately. Statistical significance was set at $p < 0.05$ for all analyses.

Ethical approval

was obtained from the Institutional Review Committee (IRC) of Chitwan Medical College (Approval No.: CMC-IRC/081/081/115; Date: June 8, 2025), Bharatpur, Chitwan before commencing the study. Written informed consent was obtained from parents or legal guardians of all participants after explaining the study objectives, procedures, potential risks, and benefits in the local language (Nepali). Verbal assent was obtained from children. Participation was entirely voluntary, and participants were informed of their right to withdraw from the study at any time without penalty or loss of benefits. Confidentiality was maintained throughout the study by assigning unique identification codes.

Results

A total of 300 children aged 6–11 years were included in the study. The largest age group was 11 years (19.0%), followed by 6 and 8 years (18.3% each). More than half of the participants were male (54.3%). The majority belonged to the Brahmin/Chhetri ethnic group (50.3%), and the highest proportion were studying in Grade 1 (27.0%) (Table 1). The mean ± standard deviation of age, height, weight, BMI, neck circumference (NC), waist circumference (WC), hip circumference (HC), and waist-hip ratio (WHR) for males, females, and the overall sample are presented in Table 2.

Table 1
Socio-demographic Characteristics of Children n = 300

Variables	Number	Percent
Age in years		
6	55	18.3
7	51	17.0
8	55	18.3
9	38	12.7
10	44	14.7
11	57	19.0
Sex		
Male	163	54.3
Female	137	45.7
Ethnicity		
Brahmin/Chhetri	151	50.3
Janajati	82	27.3
Dalit	39	13.0
Madhesi	28	9.3
Grade		
1	81	27.0
2	43	14.3
3	69	23.0
4	33	11.0
5	33	11.0
6	26	8.7
7	15	5.0

Table 2
Anthropometric Measurement of the Children n = 300

Variables	Sex		Overall
	Male (n-163)	Female (n-137)	
Age	8.45±1.81	8.49±1.78	8.47±1.79
Height (cm)	129.14±11.87	130.12±13.76	129.59±12.76
Weight (kg)	26.27±7.48	26.91±8.92	26.65±8.16
BMI (kg/m^2)	15.46±2.25	15.48±2.52	15.47±2.37
Neck Circumference (cm)	27.34±1.84	26.21±1.96	26.77±1.97
Waist circumference (cm)	56.76±6.68	55.35±6.79	56.11±6.76
Hip Circumference (cm)	65.52±7.55	68.12±9.07	66.71±8.36
Waist Hip Ratio (cm)	0.86±0.51	0.81±0.05	0.84±0.05

Continuous variables are shown as Mean±Standard deviation

Table 3
Nutritional Status of the Children n = 300

Variables	Number	Percent
Height for age		
Stunted	97	32.3
Normal	180	60.0
Tall	23	7.7
Weight for age		
Underweight	151	50.3
Normal	102	34.0
Overweight	47	15.7
BMI for age		
Underweight	124	41.3
Normal	145	48.3
Overweight	31	10.3
Neck circumference		
Normal	206	68.7
Overweight	94	31.3
Waist Hip Ratio		
Normal	247	82.3
Overweight	53	17.7

Table 3 presents the nutritional status of the respondents based on anthropometric indices. With respect to height-for-age, the majority of children were classified as normal (n = 180, 60.0%), while 97 (32.3%) were stunted and 23 (7.7%) were tall. In terms of weight-for-age, 151 (50.3%) children were underweight, 102 (34.0%) had

normal weight, and 47 (15.7%) were overweight. According to BMI-for-age classification, 145 (48.3%) children had normal BMI, 124 (41.3%) were underweight, and 31 (10.3%) were overweight. Furthermore, based on neck circumference classification, the majority of participants (n = 206, 68.7%) were categorized as normal. WHR showed majority of children were normal (n = 247, 82.3%).

Table 4
Association between Respondents' Neck Circumference and other Anthropometric Measurements n = 300

Variables	Neck Circumference		χ2	p-value
	Normal	Overweight		
	No. (%)	No. (%)		
BMI for age			52.329	0.00
Underweight	106 (85.5%)	18 (14.5%)		
Normal	94 (64.8%)	51 (35.2%)		
Overweight	6 (19.4%)	25 (80.6%)		
Height for age			20.179	0.00
Stunted	79 (81.4%)	18 (18.6%)		
Normal	119 (66.1%)	61 (33.9%)		
Tall	8 (34.8%)	15 (65.2%)		
Weight for age			93.760	0.00
Underweight	120 (79.5%)	31 (20.5%)		
Normal	82 (80.4%)	20 (19.6%)		
Overweight	4 (8.5%)	43 (91.5%)		
Waist hip ratio			1.226	0.26
Normal	173 (70.0%)	74 (30.0%)		
Overweight	33 (62.3%)	20 (37.7%)		

*Significant association at $p < 0.05$ (dup: abstract ?)

Table 4 demonstrates a statistically significant association between neck circumference and BMI-for-age, height-for-age, and weight-for-age ($p < 0.001$). However, no statistically significant association was observed between neck circumference and waist–hip ratio ($p = 0.26$).

Table 5
Pearson Correlation between Neck Circumference and other Anthropometric Variables

Variables	Neck Circumference	
	r	*p*-value
Height	0.639	0.000
Weight	0.792	0.000
BMI	0.723	0.000
Waist Circumference	0.797	0.000
Hip Circumference	0.734	0.000
Waist Hip Ratio	0.050	0.386

*Significant association at $p < 0.05$

Table 5 indicates a statistically significant positive correlation between neck circumference and height, weight, BMI, waist circumference, and hip circumference ($p < 0.001$ for all). In contrast, no significant correlation was observed between neck circumference and waist-hip ratio ($p = 0.386$).

Table 6
Receiver Operating Characteristics (ROC) Curve and Area Under the Curve Analysis for Neck Circumference

Characters	AUC	p-value	95% CI	Cutoff	Sensitivity	1-Specificity	Youden's Index (J)
Male	0.884	0.000	0.806–0.963	27.75 cm	0.889	0.338	0.551
Female	0.904	0.000	0.840–0.967	26.75 cm	1	0.306	0.694
Total sample	0.883	0.000	0.829–0.938	27.25 cm	0.806	0.257	0.549

Receiver operating characteristic (ROC) analysis identified an optimal NC cutoff of 27.75 cm for boys (sensitivity: 88.9%; specificity: 66.2%; AUC: 0.884; Fig. 1) and 26.75 cm for girls (sensitivity: 100%; specificity: 69.4%; AUC: 0.904; Fig. 2). The aggregate threshold was established at 27.25 cm, yielding 80.6% sensitivity and 74.3% specificity, with an overall AUC of 0.883 (Fig. 3). The details of of these findings are presented in Table 6.

Discussion

Neck circumference (NC) is increasingly recognized as a practical anthropometric indicator for identifying childhood obesity. However, its application in pediatric populations remains limited due to the lack of standardized reference values. The present study evaluated the utility of NC for detecting obesity among school-aged children (6–11 years) and established sex-specific cutoff points with good diagnostic performance.

Nutritional Profile of the Study Population

The study revealed a dual burden of malnutrition among the participants. While 48.3% of children had normal BMI-for-age, a substantial proportion were underweight (41.3%), and 10.3% were overweight. Similarly, 50.3% of children were underweight based on weight-for-age, and 32.3% were stunted according to height-for-age. These findings reflect the coexistence of undernutrition and emerging overweight/obesity within the same population, a phenomenon increasingly observed in developing countries undergoing nutritional transition. The relatively lower proportion of overweight children compared to underweight children indicates that undernutrition remains a significant public health concern; however, the presence of overweight cases highlights the growing importance of early obesity screening.

Globally, childhood overweight and obesity are rising. According to the World Health Organization (2025), more than 390 million children and adolescents aged 5–19 years were overweight in 2022, with a global prevalence of approximately 20%(7). Similar findings were revealed in the study by Aguilar Liendo et. al., which showed more than a third of schoolchildren had malnutrition by excess (24% overweight and 10% obesity)(4). Although the proportion of overweight children in the present study (10.3%) is lower than the global estimate, the presence of excess weight alongside high undernutrition reflects nutritional transition and underscores the importance of early screening strategies.

Association between Neck Circumference and Anthropometric Indicators

The present study demonstrated a statistically significant association between NC and BMI-for-age, height-for-age, and weight-for-age ($p < 0.001$), while no significant association was observed with waist–hip ratio (WHR). Pearson correlation analysis further revealed strong positive correlations between NC and weight ($r = 0.792$), waist circumference ($r = 0.797$), BMI ($r = 0.723$), hip circumference ($r = 0.734$), and height ($r = 0.639$), all statistically significant. However, no significant correlation was found between NC and WHR ($r = 0.050$, $p = 0.386$).

These findings are consistent with previous literature demonstrating the utility of NC as an anthropometric marker of adiposity in pediatric populations. A study conducted among schoolchildren aged 10–12 years reported strong correlations between NC and waist circumference as well as BMI-z ($r > 0.8$; $p < 0.001$), with area under the curve (AUC) values exceeding 0.90 across age and sex groups(4). Similarly, Malini et al. found significant positive correlations between NC and BMI ($r = 0.84$ in boys and $r = 0.75$ in girls) and between NC and WC ($r = 0.87$ in boys and $r = 0.84$ in girls) among children under 12 years(8). A study by Patnaik et al reveled that BMI was positively correlated with neck circumference ($r = 0.642$ for boys, 0.615 for girls) and waist circumference ($r = 0.693$ for boys, 0.682 for girls) at significant level ($p < 0.001$)(9).

Furthermore, previous studies have demonstrated that NC performs relatively well in classifying overweight (AUC: 0.67–0.75, $p < 0.001$), general obesity (AUC: 0.81–0.85, $p < 0.001$), and abdominal obesity (AUC: 0.73–0.78, $p < 0.001$) across age groups and sexes(10).

Other investigations have similarly reported satisfactory predictive ability of NC for identifying overweight and obesity among school children(11–13). Collectively, these findings, together with the results of the present study, reinforce the validity of NC as a practical and reliable marker of both general and central adiposity in children

The absence of correlation between NC and WHR in the current study may be explained by limited variability in WHR among children and developmental differences in fat distribution during prepubertal years. WHR may be less sensitive in pediatric populations compared to direct measures such as BMI and WC.

Diagnostic Performance and Cut-off Values of Neck Circumference

ROC curve analysis in the present study demonstrated excellent discriminatory ability of NC for detecting obesity. The AUC was 0.884 in boys and 0.904 in girls, with an overall AUC of 0.883, indicating high diagnostic accuracy. The identified cutoff values were; 27.75 cm for boys (Sensitivity 88.9%, Specificity 66.2%), 26.75 cm for girls (Sensitivity 100%, Specificity 69.4%), and 27.25 cm overall (Sensitivity 80.6%, Specificity 74.3%).

These values are comparable with those reported in other studies. Asif et al. reported prepubertal NC cutoffs ranging from 26.36–26.78 cm in boys and 25.02–25.27 cm in girls, while broader age-group cutoffs ranged between 25.27–30.35 cm in boys and 25.00-31.62 cm in girls(14). The cutoff values identified in the present study fall within these reported ranges, supporting their external validity.

Malini et al. identified a cutoff of 26.5 cm for both boys and girls aged 6–11 years, with AUC values of 0.86 in boys and 0.82 in girls; slightly lower than those observed in the present study(8). H. T. et al. reported higher cutoff

values (32 cm in boys and 30 cm in girls) with high sensitivity and specificity(15). Variations in cutoff values across studies may be attributed to differences in ethnicity, nutritional status, age distribution, pubertal stage, and body composition. Importantly, Asif et al. also highlighted that NC cut-offs differ between prepubertal and pubertal children, suggesting that age and sex specific reference values are necessary(14). This study, focusing on children aged 6–11 years (primarily prepubertal), identified cut-offs that are consistent with prepubertal ranges reported in the literature.

Implications

The present findings, consistent with previous studies, support the use of NC as a reliable screening tool for childhood obesity. NC measurement offers several practical advantages:

- It is simple, quick, and inexpensive.
- It does not require removal of clothing.
- It demonstrates good inter- and intra-observer reliability.
- It is less influenced by abdominal distension compared to waist circumference.

Given its strong correlation with established anthropometric indices and good diagnostic accuracy, NC can be particularly useful in school-based screening programs and resource-limited settings.

Limitations

Despite its promising utility, a major limitation remains the absence of universally established age and sex specific NC percentiles. Although the present study provides locally relevant cutoff values, further large-scale, multicenter, and longitudinal studies are required to develop standardized reference charts and validate NC across diverse populations.

Conclusion

In conclusion, the present study demonstrates that neck circumference is significantly associated with BMI, weight, height, waist circumference, and hip circumference and shows high diagnostic accuracy for detecting obesity among children aged 6–11 years. NC appears to be a feasible, reliable, and cost-effective anthropometric measure for screening childhood obesity, particularly in school and community settings.

Abbreviations

BMI
Body mass index
NC
Neck circumference
WC
Waist circumference
HC
Hip circumference
WHR
Waist to hip ratio
ROC
Receiver operating characteristic
AUC
Area under curve
WHO
World health organization

Declarations

Ethical approval and consent to participate

Ethical approval was obtained from the Institutional Review Committee (IRC) of Chitwan Medical College (Approval No.: CMC-IRC/081/081/115; Date: June 8, 2025). Written informed consent was obtained from parents or legal guardians of all participants after explaining the study objectives, procedures, potential risks, and benefits in the local language (Nepali). Verbal assent was obtained from children.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflict of interests.

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None

Author Contribution

SB contributed to the conception of the work, data collection, statistical analysis, and drafting the manuscript. SN and PS contributed to data collection, statistical analysis, and critical revision of the manuscript. All authors approved the final version to be published.

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Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Figures

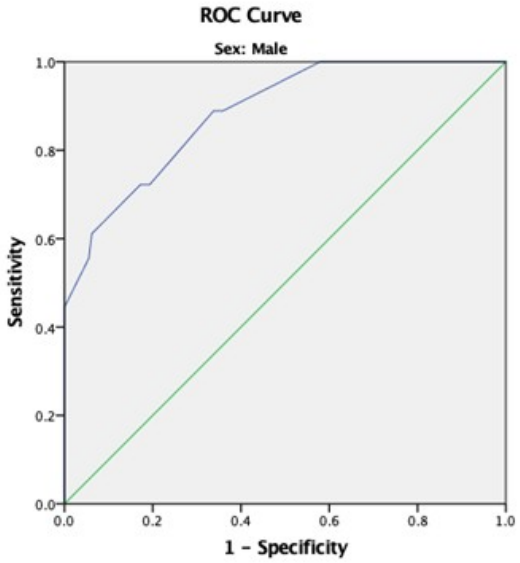


Figure 1

Receiver Operating Characteristics (ROC) Curve of Boys

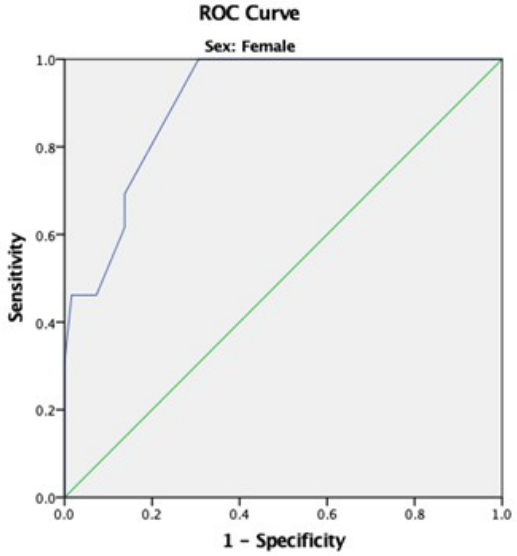


Figure 2

Receiver Operating Characteristics (ROC) Curve of Girls

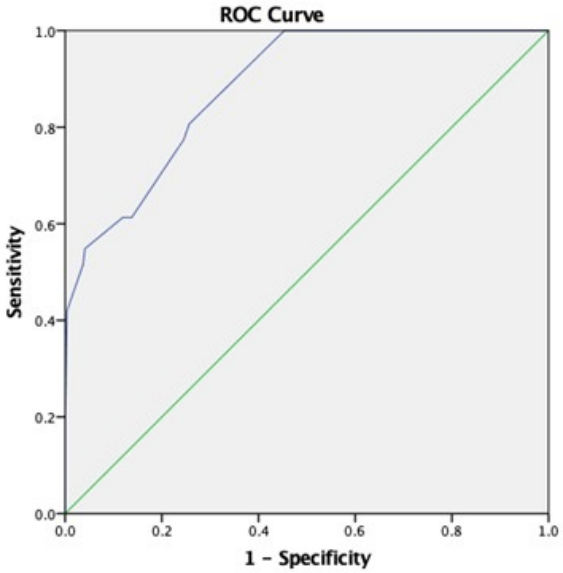


Figure 3

Receiver Operating Characteristics (ROC) Curve of Girls