Original Article

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Diagnostic Performance of Neck Circumference and Cut-off Values for Identifying Overweight and Obese Pakistani Children: A Receiver Operating Characteristic Analysis

Short Title: Neck Circumference Cut-offs for Obese Children

Muhammad Asif [1*], Muhammad Aslam[2], Justyna Wyszyńska[3], Saima Altaf [2], Shakeel Ahmad[2]
[1]Department of Statistics, Govt. Degree College, Qadir Pur Raan Multan, Pakistan
[2]Department of Statistics, Bahauddin Zakariya University, Multan, Pakistan
[3]Medical College of Rzeszów University, ul. Kopisto 2a, 35-959 Rzeszów, Poland

What is already known on this topic?
Childhood obesity is a growing problem in Pakistan, therefore there is a need to determine quick and simple tool for screening obesity. Neck circumference (NC) may be a valuable tool for screening individuals with overweight/obesity.

What this study adds?
This is the first study evaluating the correlation between NC and body mass index among Pakistani children.
We also determined the most sensitive and specific cut-off points of NC for identification of overweight and obese children using receiver operating characteristic (ROC) analysis.

Abstract
Objective: Neck circumference (NC) is considered to be an alternative screening method for obesity. The aims of this investigation were (1) to examine the correlation between BMI and NC and (2) to determine diagnostic performance, the best cut-off points of NC for identification of overweight and obese Pakistani children.
Methods: We studied a sample of 7921 children aged 5-14 years by a cross-sectional survey carried-out in four major cities of Pakistan. Receiver operating characteristic (ROC) analysis was used to see the diagnostics performance of NC and to determine the optimal cut-off points for identifying children with overweight and obesity.
Results: The mean of each anthropometric variable (i.e., height, weight, BMI and NC) increased with age in both sexes. In the overall sample studied, NC also had a good positive correlation ($r=0.61$, $p<0.01$) with BMI. NC optimal cut-off points for identifying overweight and obesity in Pakistani boys ranged between 25.00 to 30.35 cm and the corresponding values for the girls were 24.00 to 31.62 cm. In the prepubertal period, NC cut-off points indicative overweight, in both boys and girls were 26.36 cm and 25.27 cm, respectively; the corresponding values for obesity were 26.78 cm and 25.02 cm. The cut-off values of 28.32cm and 28.57cm for overweight and obesity; were reported in boys and 28.70 cm and 28.82 cm in girls at puberty stage.
Conclusion: NC could potentially be used as a simple and widely-acceptable indicator in clinical settings for identification of overweight and obesity with a reasonable accuracy in children.
Keywords: Body mass index; LMS method; Neck circumference; Obesity; Receiver operating characteristic curve**.**

Corresponding author: Muhammad Asif Lecturer
Department of Statistics, Govt. Degree College, Qadir Pur Raan Multan, Pakistan.
E-mail: asifmalik722@gmail.com; Contact: +923326038247, +923047928081
http://orcid.org/0000-0002-4406-7755
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Introduction

In recent decades, obesity is increasing considered to be a global public health issue.[1-4] Children and adolescents are the worst affected group from this serious threat with an estimated 10% of the world's school going children being overweight and one quarter of these being obese.[4,5] In developing countries including Pakistan, childhood obesity is also growing at a fast pace. Different studies[7-9] in various settings shows that the prevalence of overweight and obesity in Pakistani children ranges from 5% to 20%.
To measure obesity prevalence in children and adults, there are various anthropometric measures. However, epidemiological researchers usually use the internationally reputed criteria body mass index (BMI), which is calculated as; an individual's weight in kilograms (Kg.) divided by height in meters squared.[2] Despite the popularity of BMI and ease of use, it is becoming increasingly clear that it is not a good measure for regional adiposity, especially upper body fat distribution of an individual.[10] Currently, neck circumference (NC) is an alternative screening method, proposed as a potential proxy for obesity.[11, 12] Measurement of NC is an easy, quick and inexpensive method and now various pediatric investigators[13, 14] have attempted to use it for screening of overweight and obese children. Studies with different pediatric sample showed that the NC performed well as an index of high BMI in young children and adolescents.[13, 15, 16]
However in Pakistan, there is a scarcity of data about the use of NC as an indicator of overweight and obesity in children. Only one investigator[17] has attempted to use NC to screen for high BMI among young adults aged 18-20 years. Considering such a negotiable gap, we carried out the present study with the following objectives: i) to evaluate the correlation between NC and BMI in children and ii) to determine diagnostic performance and the best NC cut-off points for identification of overweight and obese Pakistani children.

Material and Methods

The present school based cross-sectional study was conducted between March and June, 2016. The details of the sampled

population and sampling methodology of this study has been described previously.[18-20] Here we highlight a description of the sampling procedure. For data collection, four major cities of Pakistan were considered: the city Lahore is considered as the 2nd most populated city in Pakistan with a high human development index (HDI= 0.877); the city Multan in the center of Pakistan with HDI= 0.718 and two adjacent cities Rawalpindi and Islamabad (the capital city of Pakistan) were also considered for sample collection. The HDI of these cities are 0.871 and 0.875, respectively.[21] A grade-wise complete list of schools (i.e., primary and secondary schools) of the selected cities was obtained from Punjab and the Federal Department of Education (Schools) and schools were chosen by using simple random sampling from the lists. In each selected school, classes were also selected randomly and all the children who were present on the day of data collection were invited to participate in the study. For this investigation, a sample of 7921 children aged 5-14 were recruited from a total of 68 schools (Public schools=28, Private schools =40) visited for the study.

After obtaining written consent from the school's head and verbal consent from each child's parents or guardians, data collection activities were performed. All information related to age (years), sex, residential city, and anthropometric measurements i.e., height (cm), weight (kg) and NC (cm) of each child were chronicled in a self-designed questionnaire. Age of each child was confirmed from the school register and physical measurements were taken in standing position under standard protocol.[20, 22] For anthropometric measurements; a stadiometer Seca: SCA 217, was used for height, weighing machine Westpoint. WF 7009 for weight. Neck circumference of children was taken in centimeter, using non-stretchable plastic tape measure. Measurement was taken in a horizontal plane, with participants' shoulders down and looking straight ahead, at a point just below the thyroid cartilage and perpendicular to the long axis of the neck. This location was chosen, as it is the most easily palpable landmark of the pediatric airway. During the measurement process, attention was paid not to engage the muscles shoulder / neck (trapezoid). The average of two readings was used for the analysis. All NC measurements were performed by the same experienced investigator. BMI of each child was calculated as: BMI = weight (Kg)/height (m^2) and age-and-sex specific BMI z-scores were obtained by using the LMS method.[23] For defining overweight and obesity of a child, WHO 2007 z-scores cut-offs (> +1SD i.e. BMI z-score > 1; for overweight and > + 2 SD i.e. BMI z-score > 2; for obesity) were used. [24, 25]

For the descriptive analysis, means ± standard deviation (SD) and 95% confidence intervals (CI) were estimated for each sex, varying at different ages. Mean differences of NC between two groups were determined using an unpaired t-test. For both sexes, the correlation between NC and other quantitative variables were estimated using Pearson's correlation. Odds ratios (ORs) were also computed to determine the strength of association. Age- and- sex specific diagnostic ability and cut-off values of NC were calculated with receiver operating characteristic (ROC) curve analysis according to two depended variables; overweight defined by BMI z-score > 1 and obesity defined by BMI z-score > 2. [24, 25] An NC value with the highest Youden's index was chosen for best cut-off point. The diagnostic ability of NC to discriminate children with or without overweight and obesity was assessed using area under the curve (AUC). The diagnostic test was considered to be "highly accurate if, $0.65 \leq AUC \leq 1.00$" and "moderately accurate if, $0.50 \leq AUC \leq 0.65$". [26,27] Following Nafiu et al. [28] the likelihood ratios (positive [LR^P] and negative [LR^N]) for NC were also computed for each age and sex. Sex-specific NC cut-off points according to puberty periods were also determined. Boys between 5-11 years and girls between 5-10 years were considered to be in prepubertal period; boys and girls over 11 and 10 years, respectively were in pubertal period. These age-groups were chosen after following a previously published research.[13]

For this study, exclusion criteria were: (a) children who refused to perform anthropometry (b) children who had goiter or any physical disability and (c) children who were absent at the time of data collection. The study was approved by the Departmental Ethics Committee of Bahauddin Zakariya University, Multan, Pakistan (IRB# SOC/D/2715/19). The software; "Statistical Package for Social Sciences (SPSS)" version 21.0 was used for all the statistical analyses.

Results

A total of 7921 children aged 5-14 years were included in the study. The mean BMI and NC were 16.16 Kg/m^2 and 26.00 cm, respectively. Age- and- sex-specific mean (± SD) and 95% CI of each anthropometric measurement are listed in Table 1. For each anthropometric variable, mean increased with age in both boys and girls. Generally, boys had higher mean values than girls with few exceptions.

Table 2 presents age and sex-specific mean comparison of NC according to overweight and obesity status. For the both genders in different age groups, it was observed that the mean value of NC was higher in subjects that were overweight or obese than in the other subjects. The results were also statistically significant in different ages except in 7 year old obese boy.

The values of correlation co-efficient of NC with other anthropometric measurements are displayed in Table 3a. We found that the NC had a strong positive correlation with age and all the other anthropometric measures in both genders as well as in all the subjects studied. The results of logistic regression analysis also showed that NC had a statistically significant positive association with overweight and obesity. The crude ORs for overweight and obesity were 1.43 (95% CI: 1.39, 1.46) and 1.42 (95% CI: 1.36, 1.49) and adjusted ORs for overweight and obesity were 1.74 (95% CI: 1.67, 1.80) and 1.76 (95% CI: 1.67, 1.86), respectively (Table 3b).

Table 4 displays the results of AUC for boys and girls of all ages (5-14 years). In all age-groups of both genders, diagnostic performance of NC was 'highly accurate' in classifying the individuals to overweight (AUC= 0.67 to 0.83) and obesity (AUC= 0.66 to 0.97). Diagnostic performance comparison between participants in prepubertal and pubertal period showed that the AUC was statistically lower in the prepubertal period e.g., for prepubertal boys, the AUC of overweight (0.75) and obesity (0.78) was lower than the pubertal overweight (0.78) and obese boys (0.85). The ROC curves accurately define overweight and obesity of the overall (i.e., 5-14 years) Pakistani children of both sexes are also shown in Figure 1.

Based on the ROC analysis, sensitivities, specificities, and cut-off points for each age-group by gender are presented in Table 5. NC cut-off values for overweight and obesity increased from 25.00 to 30.35cm for boys and 24.00 to 31.62cm for girls between 5 and 14 years. In the prepubertal period, NC cut-off values for overweight and obesity were 26.36 and 26.78cm in boys and 25.27 and 25.02cm, in girls, respectively. For the pubertal period, these cut-off values were 28.32 and 28.57cm in boys and 28.70 and 28.82cm in girls. Considering all the children included in the study, the cut-off points of NC that identified overweight and obesity in boys and girls were 27.05 cm and 27.56 cm for boys and 26.55 cm and 27.81 cm for girls, respectively. The likelihood ratios for each cut-off point were also calculated. For example, LR^P for a 14-years old boy with NC > 30.35cm indicates that he is 2.64 times more likely to be overweight than a 14-years old boy with NC value below this cut-off point.

Discussion

Obesity in children is now considered to be a serious chronic health issue in most populations [29] and its worldwide prevalence is growing alarmingly.[30] Various studies [3, 31] in the literature are available that report increased adverse health outcomes of childhood obesity with short-term and long-term consequences. Early prevention and treatment of childhood obesity are important priorities for health practitioners that need accurate diagnostic measures.[32] Different practical methods such as BMI, WC, and WHR are applicable for assessing obesity. But in the circumstances where these methods are not feasible, measurement of NC may be an alternative, reliable and easy to use index that is generally acceptable to patients and health practitioners.[12, 13, 15] Some studies [12, 13] in the pediatric age group confirmed that NC value measurements could be used as an index of overweight and obesity. Following these, we also planned a study for identifying overweight and obese Pakistani children using NC measurement.

Validation of NC against WC and BMI reported by Hatipoglu et al.[13] showed that NC could serve as an easy way to determine overweight and obesity in children with good correlation to cardiovascular risk factors. A study [33] on Greek children aged 9-13 years also indicate that NC is associated with cardiovascular risk factors. Moreover, the NC measurement was confirmed as a reliable anthropometric index to predict children with cardio metabolic disease.[34]

In the present study, the results revealed that NC has a good correlation with BMI and other anthropometric characteristics. These findings are consistent with earlier studies [14, 35] that show NC has a significant positive correlation with age and anthropometric variables in both genders. The NC increased with age in both genders and mean values of NC were higher in overweight and obese children as compared to the normal subjects. These findings are in accordance with a previous population-based reported study[36] for Iranian children and adolescents, aged 6-18 years. Also consistent with more recent studies,[37,38], the present study yields NC in overweight/obese adolescents that are significantly higher than adolescents with normal BMI ($P < 0.001$).

In our study, results for AUC values between 70% and 90% in various age-groups were similar to those found in an Iranian cross-sectional study[36] suggesting that NC could serve to accurately identify children that are overweight or obese. Another Brazilian study by Souza et al.[39] has also established the NC as an adequate indicator to identify adolescents with high BMI. Similar to two recent studies, [40, 41], the present study results also suggest that NC has good diagnostic ability (i.e., AUC > 0.65) for identifying overweight and obesity in children and adolescents and could be used to screen for excess body weight in routine medical practice. Furthermore, the cut-off point of NC to identify children that are overweight in different age-groups was between 25.00 - 30.35 cm and 24.00 - 29.33 cm for boys and girls, respectively. The cut-off points of NC to identify children that are obese in different age-groups was between 25.27 - 30.35 cm and 25.00 - 31.62 cm, for boys and girls; respectively. While, larger NC cut-offs (i.e., from 28.0 to 38.0 cm in boys and from 27.0 to 34.5 cm in girls) in both sexes were observed in Turkish study for the prediction of overweight and obesity.[13] Similarly, larger cut-off values of NC for the prediction of overweight and obesity were also noted in an Iranian population-based study.[36] Another Iranian study by Taheri et al.[16] also described the comparison in NC cut-offs, sensitivity and specificity values among different countries. A notable variation was observed in the cut-off values of NC, sensitivity and specificity across the countries. Our findings also suggest an action level lower than previous published studies.[13, 16, 36] Gender-and-ethnic differences in body size might partially explain the heterogeneity in the optimal cut-offs among different populations. Furthermore, differences in sensitivity, specificity of the NC measuring method in different studies may be explained due to sample size and age range (i.e. 5-14 years in the present study). Furthermore, in our study, BMI-for-age z-scores were calculated by using the LMS method. Also, no study in the literature determined the BMI-for-age z-scores using this method. Such methodological diversity can also influence these values. The optimal cut-off may vary according to age and additional studies using the same methodology and assessing a wide age range are needed.

Our study has several strengths. Firstly, no similar study has already been planned to determine the best cut-off points of NC for identification of overweight and obese Pakistani children using a multi-ethnic data set. Secondly, our study results using ROC curve analysis are likely to be representative of today's children and these results are exclusively applicable at a national level, and possibly at the regional level. Moreover NC measures were collected by the same researcher, which reduces possible inter-observer biases. A limitation of this study is that the causal pathways underlying the observed relationships could hardly be detected, due to a cross-sectional study design. Second limitation is that our study does not cover all age ranges of children and adolescents from birth to 18 years of age. It should be taken into account that NC measurements for screening obesity may be unreliable for individuals with different health problems manifested by changes in the neck, such as malignancy or thyroid diseases, orthopedic problems regarding cervical spine disorders; short neck; craniofacial anomalies or neurological conditions or underlying cardiac or pulmonary disease. In spite of the limitations, we believe that the results of this study will contribute new information for knowledge of Public Health.

Conclusion

We demonstrate that NC has good correlation with BMI and also has good diagnostic performance for identifying overweight and obese children. Therefore, NC could be proposed as a simple and valuable tool for children with overweight and obesity. Results suggested that boys and girls aged 5-14 years with NC range; ≥ 25.00 to 30.35 cm and ≥ 24.00 to 31.62 cm, respectively, are considered to be overweight and obese. Some epidemiological researchers also used NC as a screening method to evaluate cardiovascular and metabolic risk in obese children and adults. Therefore, more studies with Pakistani children and young adults should be established to appraise the usefulness of NC as an index of adiposity.

Declarations

Consent for publication:

Not applicable

Availability of data and material:

The datasets used for the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Author's contributions:

MA[a], main investigator, conceived the idea, designed, statistical analysis and interpret the results of the study. MA[b] shared his expert opinion in sampling design, data collection process and critically analyzed the data for important intellectual content and also gave his input in manuscript drafting and submission, JW[c] also studied it critically for important intellectual content and gave his expert opinion in finalizing the manuscript, SA[d] and SA[e] conceived the study and co-drafted the manuscript; all authors read and approved the manuscript as submitted.

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Table1: Descriptive statistics (95% CI) for Height, Weight, BMI and NC by age

Age (Yrs)	Height (cm)		Weight(kg)		BMI (kg/m^2)		NC (cm)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
05	112.78±7.13 (111.87,113.69)	111.30±7.38 (110.55,112.03)	19.05±3.77 (18.57,19.53)	18.16±3.26 (17.83,18.49)	14.92±2.28 (14.63,15.21)	14.64±2.14 (14.43,14.85)	23.93±1.88 (23.75, 24.23)	23.42±1.62 (23.27, 23.59)
06	119.36±7.81 (118.46,120.26)	117.15±6.99 (116.46,117.83)	21.39±4.23 (20.90,21.87)	20.07±3.51 (19.73,20.42)	14.94±2.11 (14.70,15.18)	14.58±1.85 (14.40,7.76)	24.33±1.77 (24.13, 24.54)	23.71±1.76 (23.54,23.88)
07	123.70±7.18 (122.85,124.54)	122.21±7.64 (121.44,122.99)	23.19±4.59 (22.65,23.73)	22.51±4.65 (22.04,22.98)	15.07±2.21 (14.82,15.33)	14.98±2.11 (14.76,5.19)	24.48±1.82 (24.26, 24.69)	24.10±1.62 (23.94,24.27)
08	128.21±7.63 (127.30,129.12)	127.55±8.07 (126.73,128.37)	25.14±5.23 (24.52,25.76)	25.38±5.69 (24.81,25.96)	15.20±2.19 (14.94,15.46)	15.48±2.34 (15.24,15.72)	24.88±1.81 (24.68, 25.10)	24.91±1.84 (24.72, 25.09)
09	132.65±7.18 (131.75,133.55)	130.73±6.65 (130.01,131.44)	27.33±5.44 (26.65,28.01)	27.14±5.60 (26.54,27.74)	15.45±2.31 (15.16,15.74)	15.79±2.48 (15.52,16.05)	25.16±2.02 (24.90, 25.41)	25.36±2.07 (25.14,25.58)
10	139.19±7.76 (135.44,136.93)	132.59±7.93 (132.26,133.71)	29.44±6.32 (28.83,30.04)	28.64±5.55 (28.13,29.15)	15.75±2.37 (15.53,15.98)	16.14±2.47 (15.51,16.37)	25.64±1.78 (25.47, 25.81)	25.78±2.05 (25.59,25.96)
11	140.09±7.89 (139.36,140.84)	138.37±8.05 (137.49,139.25)	31.75±6.08 (31.18,32.32)	31.67±7.03 (31.90,33.44)	16.11±2.42 (15.89,16.35)	16.96±2.75 (16.68,17.26)	26.30±1.78 (26.13, 26.46)	26.56±2.16 (26.33, 26.80)
12	144.45±8.28 (143.82,145.07)	142.97±8.60 (142.15,143.78)	34.31±7.03 (33.78,34.84)	35.50±7.31 (34.81,36.19)	16.35±2.57 (16.16,16.55)	17.27±2.63 (17.02,17.09)	26.69±2.03 (26.53, 26.84)	27.17±2.04 (26.98,27.37)
13	149.07±9.28 (148.33,149.82)	148.96±8.77 (148.16,149.76)	37.81±7.93 (33.17,38.45)	39.73±7.70 (39.03,40.44)	16.90±2.59 (16.69,17.11)	17.83±2.66 (17.58,18.07)	27.43±2.02 (27.27, 27.60)	27.83±2.19 (27.63,28.03)
14	156.52±9.28 (156.14,157.68)	150.50±8.87 (149.56,151.44)	43.53±8.81 (42.80,44.26)	41.89±7.89 (41.04,42.74)	17.57±2.63 (17.35,17.78)	18.42±2.72 (18.13,18.71)	28.54±2.13 (28.57, 28.92)	28.76±2.15 (28.33,28.99)
5-9	123.36±9.96 (122.82,123.90)	121.49±10.11 (121.04,121.96)	23.22±5.45 (22.92,23.51)	22.51±5.64 (22.25,22.76)	15.11±2.22 (14.99,15.23)	15.07±2.23 (14.97,15.17)	24.57±1.90 (24.46, 24.67)	24.27±1.91 (24.18,24.36)

10-14	146.08±11.05 (145.66,146.50)	142.60±10.72 (142.13,143.06)	35.83±8.81 (35.50,36.17)	35.53±8.58 (35.15,35.90)	16.60±2.61 (16.50,16.69)	17.29±2.75 (17.17,17.40)	27.05±2.23 (26.97, 27.14)	27.14±2.32 (27.04,27.24)

Values expressed as mean ± SD

Table2: Mean comparison of NC according to overweight and obesity status in children by age and sex.

Age (Years)-sex group	**Overweight status**		**Obesity status**	
	Yes	**No**	**Yes**	**No**
Age group-boys				

05	25.33±2.29	23.79±1.73 *	25.74±1.88	23.93±1.85 *
06	26.34±2.27	24.09±1.54 *	27.50±2.60	24.21±1.61 *
07	26.05±2.27	24.18±1.56 *	25.25±2.61	24.46±1.80
08	26.49±1.98	24.63±1.65 *	27.50±2.17	24.77±1.71 *
09	26.96±2.39	24.88±1.82 *	27.46±2.44	25.07±1.90 *
10	27.25±1.91	25.34±1.59 *	28.29±1.83	25.54±1.70 *
11	27.55±1.88	26.04±1.65 *	28.55±1.60	26.21±1.74 *
12	28.70±2.06	26.31±1.80 *	30.24±1.79	26.56±1.92 *
13	29.33±1.97	26.97±1.75 *	29.57±2.03	27.37±1.99 *
14	30.51±1.67	28.39±2.04 *	31.22±1.37	28.63±2.09 *
5-9	26.23±2.27	24.31±1.69 *	26.81±2.44	24.49±1.83 *
10-14	28.84±2.22	26.69±2.05 *	29.79±2.00	26.96±2.17 *
Overall (5-14 years)	28.11±2.52	25.88±2.24 *	28.82±2.56	26.14±2.37 *
Age group-girls				
05	24.42±1.98	23.29±1.51 *	24.57±2.14	23.37±1.57 *
06	25.26±2.17	23.44±1.53 *	25.40±2.05	23.66±1.73 *
07	25.77±2.10	23.86±1.38 *	25.65±2.22	24.05±1.57 *
08	26.85±2.11	24.50±1.49 *	27.80±2.59	24.80±1.70 *
09	27.20±2.74	24.99±1.69 *	28.89±3.83	25.27±1.94 *
10	27.21±2.24	25.51±1.91 *	27.39±2.90	25.73±2.01 *
11	29.23±2.48	26.15±1.78 *	31.59±1.06	26.44±2.02 *
12	29.16±2.11	26.75±1.76 *	30.24±2.24	27.07±1.96 *
13	29.51±1.90	27.47±2.08 *	30.56±1.79	27.77±2.16 *
14	30.02±2.00	28.24±2.05 *	31.11±1.06	28.51±2.14 *
5-9	25.97±2.44	23.97±1.64 *	26.20±2.88	24.20±1.84 *
10-14	29.00±2.32	26.77±2.14 *	29.93±2.54	27.07±2.28 *
Overall (5-14 years)	27.63±2.81	25.41±2.37 *	27.86±3.30	25.70±2.53 *

Values expressed as mean ± S.D;*: significant values $p < 0.01$;

Table 3a: Correlation co-efficient between NC and other anthropometric characteristics in children

Anthropometric characteristics	Neck circumference (cm)		
	Sex		
	Boys	Girls	Total
Age (years)	0.58 *	0.65*	0.62 *
Height (cm)	0.68*	0.70 *	0.69 *
Weight (kg)	0.79 *	0.80 *	0.79 *
BMI (kg/m^2)	0.59 *	0.64 *	0.61 *

Table 3b: Association of neck circumference with overweight (i.e. BMI z-score > 1) and obesity (i.e. BMI z-score > 2) in a logistic regression model

Model	Overweight	Obesity

		OR (95% CI)	OR (95% CI)
Neck circumference (cm)			
	Model I	1.43 (1.39-1.46)*	1.42 (1.36-1.49)*
	Model II	1.74 (1.67-1.80) *	1.76 (1.67-1.86) *

Model I: without adjustment
Model II: Adjusted for age, sex and city living area.
*: significant values $p < 0.01$

Table 4: AUC for detection of overweight and obesity based on the NC in children by age and sex.

Age (Years)-sex group	Overweight status			Obesity status		
	AUC (95% CI)	SE	P-value	AUC (95% CI)	SE	P-value
Age group-boys						
05	0.699 (0.592-0.806)	0.054	<0.001	0.765 (0.625-0.905)	0.071	0.007
06	0.789 (0.695-0.884)	0.048	<0.001	0.855 (0.726-0.983)	0.065	<0.001
07	0.749 (0.660-0.839)	0.046	<0.001	0.555 (0.313-0.797)	0.123	0.620^{NS}
08	0.763 (0.680-0.945)	0.042	<0.001	0.830 (0.685-0.975)	0.074	<0.001
09	0.790 (0.692-0.867)	0.050	<0.001	0.792 (0.589-0.996)	0.104	0.005
10	0.783 (0.718-0.848)	0.033	<0.001	0.855 (0.744-0.965)	0.056	<0.001

11	0.729 (0.666-0.792)	0.032	<0.001	0.836 (0.758-0.914)	0.040	<0.001
12	0.805 (0.755-0.855)	0.026	<0.001	0.908 (0.833-0.984)	0.038	<0.001
13	0.814 (0.769-0.859)	0.023	<0.001	0.785 (0.666-0.904)	0.061	<0.001
14	0.787 (0.740-0.833)	0.024	<0.001	0.844 (0.784-0.903)	0.030	<0.001
5-9	0.753 (0.710-0.796)	0.022	<0.001	0.768 (0.688-0.847)	0.040	<0.001
10-14	0.761 (0.737-0.786)	0.012	<0.001	0.826 (0.784-0.867)	0.021	<0.001
Prepubertal	**0.752 (0.721-0.783)**	**0.016**	**<0.001**	**0.784 (0.725-0.843)**	**0.030**	**<0.001**
Pubertal	**0.786 (0.758-0.814)**	**0.014**	**<0.001**	**0.850 (0.805-0.895)**	**0.023**	**<0.001**
Overall	0.747 (0.726-0.769)	0.011	<0.001	0.776 (0.733-0.819)	0.022	<0.001
Age group-girls						
05	0.672 (0.580-0.764)	0.047	<0.001	0.664 (0.496-0.831)	0.085	0.027
06	0.774 (0.704-0.843)	0.036	<0.001	0.749 (0.620-0.877)	0.066	0.003
07	0.792 (0.714-0.870)	0.040	<0.001	0.768 (0.596-0.941)	0.088	0.002
08	0.824 (0.765-0.883)	0.030	<0.001	0.841 (0.710-0.972)	0.067	<0.001
09	0.758 (0.686-0.830)	0.037	<0.001	0.771 (0.531-1.000)	0.123	0.009
10	0.724 (0.657-0.792)	0.034	<0.001	0.668 (0.486-0.849)	0.093	0.040
11	0.836 (0.768-0.904)	0.035	<0.001	0.976 (0.957-0.995)	0.010	<0.001
12	0.810 (0.752-0.868)	0.030	<0.001	0.860 (0.739-0.981)	0.062	<0.001
13	0.770 (0.714-0.827)	0.029	<0.001	0.840 (0.736-0.944)	0.053	<0.001
14	0.758 (0.688-0.828)	0.036	<0.001	0.867 (0.765-0.970)	0.052	0.002
5-9	0.761 (0.728-0.795)	0.017	<0.001	0.720 (0.643-0.797)	0.039	<0.001
10-14	0.761 (0.731-0.790)	0.015	<0.001	0.802 (0.726-0.877)	0.038	<0.001
Prepubertal	**0.748 (0.719-0.778)**	**0.015**	**<0.001**	**0.703 (0.634-0.773)**	**0.036**	**<0.001**
Pubertal	**0.788 (0.758-0.819)**	**0.016**	**<0.001**	**0.877 (0.825-0.929)**	**0.026**	**<0.001**
Overall	0.728 (0.705-0.750)	0.012	<0.001	0.694 (0.637-0.751)	0.029	<0.001

SE: Standard Error; NS: Not significant

Table 5: Cut-off point, sensitivity and specificity of NC for detecting overweight and obesity in children by sex and age groups.

Age (year)-Sex group	Overweight					Obesity				
	Cut-off point	Sensitivity	Specificity	LR^P	LR^N	Cut-off point	Sensitivity	Specificity	LR^P	LR^N
Age group-boys										
05	25.28	0.63	0.75	2.52	0.50	25.27	0.78	0.72	2.78	0.30
06	25.28	0.74	0.70	2.47	0.37	26.17	0.73	0.90	7.30	0.30
07	25.00	0.71	0.70	2.37	0.41	27.31	0.29	0.94	4.83	0.76
08	25.02	0.78	0.54	1.70	0.41	26.42	0.73	0.86	5.21	0.31
09	27.00	0.70	0.85	4.67	0.35	27.00	0.75	0.80	3.75	0.31
10	27.00	0.73	0.78	3.32	0.34	28.00	0.80	0.84	5.00	0.24
11	26.54	0.75	0.61	1.92	0.41	28.00	0.80	0.73	2.96	0.27
12	27.30	0.78	0.71	2.69	0.31	29.08	0.88	0.88	7.33	0.14
13	28.00	0.66	0.84	4.12	0.41	28.32	0.77	0.76	3.21	0.30
14	30.35	0.74	0.72	2.64	0.36	30.35	0.88	0.66	2.59	0.18
5-9	25.78	0.51	0.88	4.25	0.56	25.78	0.59	0.85	3.93	0.48
10-14	27.56	0.78	0.63	2.11	0.35	29.08	0.73	0.81	3.84	0.33
Prepubertal	**26.36**	**0.67**	**0.82**	**3.30**	**0.49**	**26.78**	**0.70**	**0.77**	**3.13**	**0.38**
Pubertal	**28.32**	**0.68**	**0.78**	**3.06**	**0.41**	**28.57**	**0.88**	**0.74**	**3.37**	**0.16**
Overall	27.05	0.66	0.73	2.45	0.47	27.56	0.76	0.70	2.53	0.34
Age group-girls										
05	24.00	0.62	0.63	1.68	0.60	25.02	0.63	0.83	3.71	0.45
06	24.76	0.67	0.81	3.53	0.41	25.00	0.67	0.76	2.79	0.43
07	25.02	0.74	0.77	3.22	0.34	25.27	0.83	0.74	3.19	0.23
08	26.00	0.63	0.90	6.30	0.41	25.78	0.77	0.83	4.53	0.28
09	26.54	0.61	0.81	3.21	0.48	27.68	0.75	0.89	6.82	0.28
10	26.79	0.54	0.84	3.37	0.55	27.68	0.58	0.81	3.05	0.52
11	27.17	0.77	0.74	2.96	0.31	30.22	1.00	0.93	14.28	0.00
12	28.32	0.60	0.88	5.00	0.45	28.32	0.86	0.82	4.78	0.17
13	28.19	0.75	0.73	2.78	0.34	28.19	0.89	0.66	2.62	0.17
14	29.33	0.71	0.74	2.73	0.39	31.62	0.67	0.92	8.37	0.36
5-9	25.27	0.71	0.72	2.54	0.40	25.02	0.74	0.66	2.18	0.39
10-14	28.32	0.59	0.82	3.28	0.50	28.32	0.76	0.76	3.17	0.32
Prepubertal	**25.27**	**0.73**	**0.67**	**2.16**	**0.40**	**25.02**	**0.75**	**0.66**	**1.88**	**0.41**
Pubertal	**28.70**	**0.67**	**0.80**	**3.33**	**0.42**	**28.82**	**0.92**	**0.72**	**3.31**	**0.10**
Overall	26.55	0.66	0.68	2.06	0.50	27.81	0.57	0.74	2.19	0.58

LR^P: Likelihood Ratio for Positive; LR^N: Likelihood Ratio for Negative

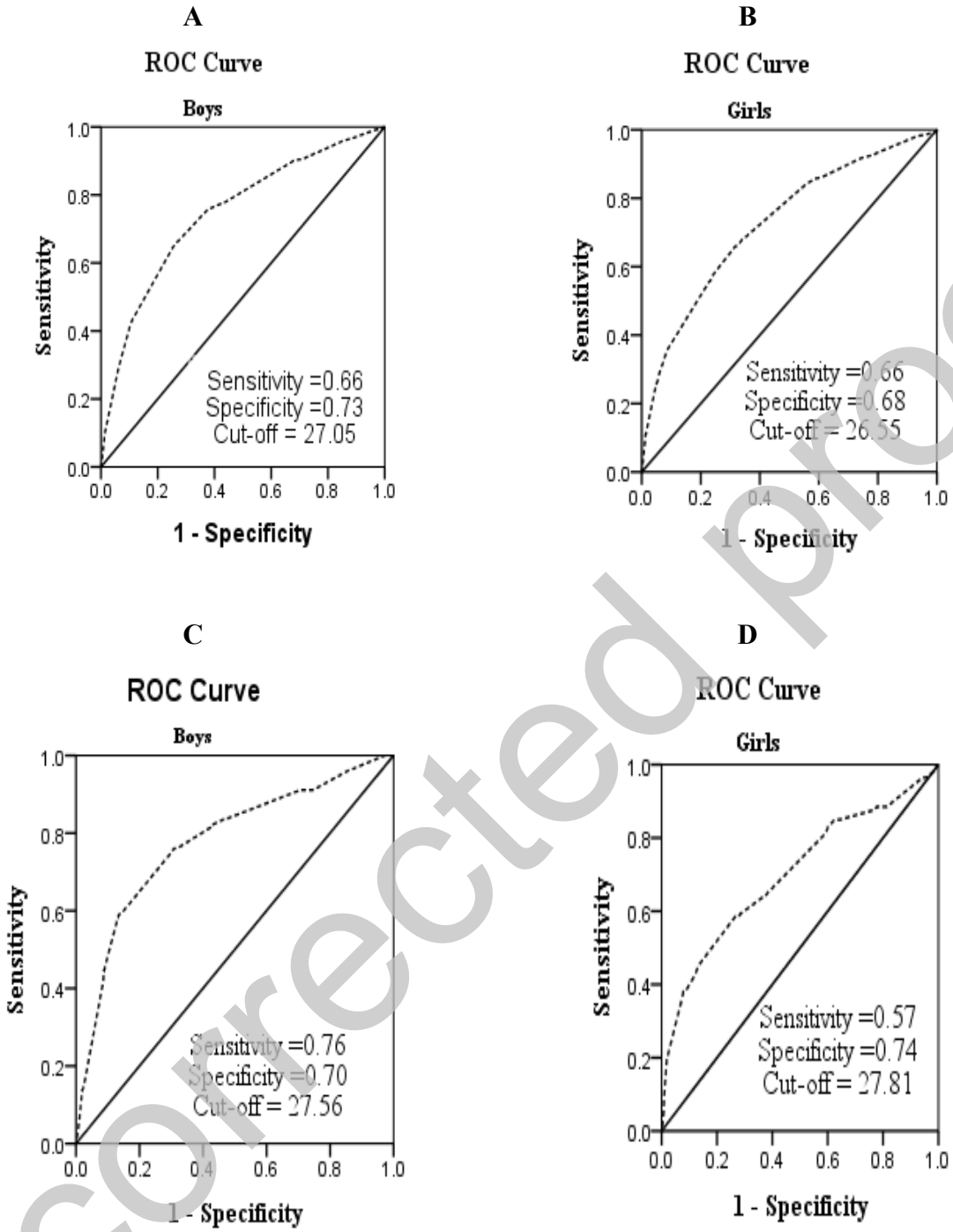

Fig.1: Receiver operating characteristic (ROC) curve of neck circumference as an indicators of overweight (A+B) and obese (C+D) Pakistani children aged, 5-14 years in both genders.