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Original Research Article

A cross-sectional study to validate neck circumference, waist circumference, wrist circumference and mid upper arm circumference as a screening tool for overweight in adolescents at school of Ahmedabad city

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ABSTRACT

Background: Obesity is a major health problem in children & adults. Due to physiological changes during growing up in children and adolescents, it is difficult to develop one simple index for measurement of overweight & obesity. So, this study was carried out to identify simple methods like neck, waist, wrist, and mid upper arm circumference used as screening tools for overweight & obesity.
Objective: To correlate neck, waist, wrist & mid upper arm circumference with BMI for prediction of overweight.
Materials and Methods: This was a cross-sectional study done on healthy urban school going children in the age group of 9 -17 years old. After measuring height and weight, BMI (body mass index) was calculated and nutritional status was classified. BMI was compared to neck, waist, wrist & mid upper arm circumferences to find out correlation. Cut off values of all four parameters to predict overweight & obesity were obtained by analysing the ROC (receiver operating characteristics) curve.
Result: Total 907 students of age group 9 to 17 years old were screened. Correlation of Neck circumference (NC), Waist Circumference (WC), Wrist Circumference (WrC) and Mid Upper Arm Circumference (MUAC) with BMI by Pearson's correlation coefficient were correlated positively. The bland Altman plots showed higher concentration of points at the 95% limit of agreement (±1.96 SD) and that the mean difference in Z-score of two tests was equal or close to zero. AUROC for NC was 0.81, for WC 0.9, for WrC 0.811 and for MUAC 0.893.
Conclusion: Neck circumference, Waist circumference, Wrist circumference and Mid upper arm circumference can be used as a screening test for predicting overweight or obesity in adolescents.

1. Background

Overweight and obesity defined as an abnormal or excessive fat accumulation that may impair health.[1] Globally there are more people who are obese than underweight – this occurs in every region except parts of sub-Saharan Africa and Asia.[2]

The prevalence of obesity has increased from 4 % in age group 5-19 years in 1975 to more than 18 % in year 2016 which numbered to 340 million.[2] In 2019, an estimated 38.2 million children under the age of 5 years were overweight or obese.

In developing countries like India, we face a double burden of disease whereas the problem of infection and undernutrition is static, there is a rapid surge in

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noncommunicable disease for which obesity is a risk factor. Newer lifestyle, junk food, TV & internet usage have contributed to this surge.

Childhood and adolescent obesity may lead to morbidity and premature deaths[3,4] and is associated with increasing chances of persisting in adulthood (tracking phenomenon).[5]

It is difficult to develop one simple index for measurement of overweight & obesity in children & adolescents because their bodies undergo a number of physiological changes as they grow depending on age & gender. So, classifications of obesity in children and teen need to be expressed relative to other children/teen of same age and gender.[6]

BMI (Body Mass Index) is a commonly used indicator for defining and classifying overweight and obesity. According to CDC, overweight is defined as BMI $\geq 85^{th}$ to $<95^{th}$ percentile and obesity is defined as BMI $\geq 95^{th}$ percentile.[7,8] According to WHO, prevalence of overweight & obesity in children and adolescent is defined as,[2]

For children aged 0-5 years

1. Overweight is weight-for-height greater than 2 SD above WHO Child Growth Standards median.
2. Obesity is weight-for-height greater than 3 SD above WHO Child Growth Standards median.

For individuals aged 5-19 years

1. Overweight is BMI-for-age greater than 1 SD above WHO Child Growth Reference median.
2. Obesity is BMI-for-age greater than 2 SD above WHO Child Growth Reference median.

BMI is also useful anthropometric index for cardiovascular risk.[9] BMI does not measure body fat directly like skinfold thickness measurements, bioelectrical impedance, densitometry (underwater weighing), dual energy x-ray absorptiometry (DXA) and other methods.[10–12] but research has shown that BMI is correlated with these direct measuring methods and also related with cardiovascular risk.

In addition to BMI; skin fold thickness, waist circumference, waist-hip ratio may be used to defined obesity.[13] But all the anthropometric measurements have limitation of convenience & standardization, So, this study was carried out as an effort to identify simple methods like neck circumference, waist circumference, mid upper arm circumference, wrist circumference & their correlation with BMI.

2. Aims and Objective

To correlate neck circumference, waist circumference, wrist circumference and mid upper arm circumference with BMI for prediction of overweight.

2.1. Study design

Cross sectional study.

2.2. Inclusion criteria

Healthy school going children of 9-17 years.

2.3. Exclusion criteria

1. Endocrine causes of obesity.
2. Chronic illnesses like HIV, Thalassemia, Nephrotic syndrome, Malignancy.
3. On AED (anti-epileptic drugs) or long-term steroids.
4. Local neck problems like swelling, cyst, goiter, cervical spine anomaly.

3. Materials and Methods

The prevalence of obesity and overweight in children and adolescents is 18% according to WHO. Using standard formula for estimating required sample size, $4pq/l^2$(p=prevalence, l=error) minimum number of children whose data is required for the study comes to be 236 with 5% absolute error, the study was conducted using convenience sampling from 28 November 2018 to 15 December 2018 in a school in an urban area of Ahmedabad city. Parents of children studying in 5^{th} to 10^{th} grade in both English and Gujarati medium were asked for consent. Out of those consenting for study and excluding those falling under exclusion criteria, 907 children were present during the period of study and their data was taken methodically.

Their anthropometric measurements were taken by trained medical personnel. Height was measured by a stadiometer with proper protocols of measuring height. Weight was measured by using a calibrated digital weighing scale to nearest accuracy 0.1 kg. BMI is calculated by dividing weight in kg by square of their height in meters (kg/m^2) & plotted on IAP growth chart 5-18 years boys and girls. According to that they were categorized as severe undernourished, moderate undernourished, normal weight, overweight & obese.

Waist circumference (WC) was measured by using non stretchable measuring tape at a level of midpoint between highest point of iliac crest and lower border of rib in mid axillary line. Neck circumference was measured at the level of thyroid cartilage with head straight in standing position with non- stretchable plastic tape.

Mid upper arm circumference was measured at the midpoint of acromion process and olecranon process in non-dominant arm extended at elbow position. Wrist circumference was measured at the level of the neck of ulna in non-dominant hands.

Data were analyzed by R statistical software (R version 3.5.3) BMI was compared to all four parameters by Pearson correlation test to find out correlation. Cut off values of

all four parameters to identify overweight and obesity were obtained by analysing the ROC (receiver operating characteristics) curve. A perfect score will have an AUC of 1, whereas AUC of 0.5 means that test performance was no better than chance.

The best cut off value for male & female children were established separately in different age groups. Children with either overweight or obesity and undernutrition were referred to hospital for further management.

4. Results

Total 907 students of age group 9 to 17 years old (mean age 12.63 with ±1.72) were screened. Among those 524 (57.77 %) were male with mean age 12.73 ± 1.78 and 383 (42.22 %) were female with mean age 12.49 ± 1.62 year. There was no statically significant difference between number of male and female

From total 907 students 56 (6.2 %) were obese, 108 (11.9 %) were overweight, 652 (71.9 %) were normal, 32 (3.5 %) were moderate under nourished and 59 (6.5 %) were sever under nourished.

There was no significant difference between the various age groups in males as well as in females in terms of distribution of Nutritional Status (X^2 = 27.394, p = 0.497 for males & X^2 = 25.887, p = 0.579 for females).

InTables 1, 2, 3 and 4, correlation of Neck circumference (NC), Waist Circumference (WC), Wrist Circumference (WrC) and Mid Upper Arm Circumference (MUAC) with BMI by Pearson's correlation coefficient are shown, which suggest all these circumferences were significantly positively correlate with BMI except age group 16-17 years in female that can be due to small sample size (n=3).

The bland Altman plots illustrated in Figure 1 show higher concentration of points at the 95% limit of agreement (±1.96 SD) and that the mean difference in Z-score of two tests was equal or close to zero.

In total number of students, Area under the ROC curve (AUROC) for Neck Circumference predicting High BMI was 0.81 (95 % CI: 0.777 - 0.843), thus demonstrating good diagnostic performance with statistically significance (p = <0.001). At a cut off of Neck Circumference (cm) >28.65, it predicts High BMI with a sensitivity of 86.6 %, and a specificity of 59.8%. Same way, the ROC curve (AUROC) for Waist Circumference predicting High BMI was 0.9 (95% CI: 0.875 - 0.925), with statistically significant excellent diagnostic performance. At a cut off of Waist Circumference (cm) >65.15, it predicts High BMI with a sensitivity of 86.0 %, and a specificity of 80.3%. In case of Wrist Circumference, area under the ROC curve (AUROC) 0.811 (95% CI: 0.777 - 0.845), thus demonstrating good diagnostic performance with statistically significance (p = <0.001) and cut off of Wrist Circumference (cm) >14.55, with a sensitivity of 73.8 %, and a specificity of 76.3%. The area under the ROC curve (AUROC) for Mid-Upper-Arm Circumference predicting High BMI vs. Controls was 0.893 (95% CI: 0.866 - 0.92), thus demonstrating good diagnostic performance. It was statistically significant (p = <0.001). At a cut off of Mid-Upper-Arm Circumference (cm) >22.9, it predicts High BMI with a sensitivity of 79.9%, and a specificity of 86.7%.

Table 5 suggests AUROC value and cut off values for total male and female students with their sensitivity and specificity for predicting High BMI.

5. Discussion

In an era of increasing obesity and overweight, Prevention is always desirable. So, awareness regarding obesity or overweight amongst children, teachers, parents and medical personnel is the key to develop preventive strategy. For that an easy, cheap, convenient screening method with good accuracy is required, so that parents, teachers, nurses or peripheral health workers could screen children or adolescents and identify high risk groups for overweight or obesity. So, in our study, we tried to correlate neck circumference, waist circumference, wrist circumference and mid upper arm circumference with BMI and to find out cut off for these parameters with diagnostic performance.

In our study the median of neck circumference, waist circumference, wrist circumference and mid upper arm circumference were statistically significantly more in the high BMI group than in the control group. (P<0.001).

In our study all these four parameters were positively correlate with BMI except in the 16-17 years old age group of females. This may be due to a lesser number of sample sizes in this age group. It means by increasing one parameter, BMI also increases.

We found AUROC of all parameters was above 0.8, Suggesting good predicting capacity of all. So, we can conclude that all these four parameters can be used as screening tests.

Furthermore, on comparing parameters with each other, AUROC of waist circumference was 0.9 which was more than other 3 parameters in group of total students and also in group of total female students (AUROC of waist circumference: 0.909 in group of total females). So, waist circumference had more capacity of predicting overweight this was also supported by study done by Lipilekha Patnaik et al[14] in which waist circumference (AUROC for waist circumference for Boys: 0.866, for girls: 0.850) was more accurate than neck circumference but Waist circumference had some limitations like changes with meal and respiration & with menstrual periods in girls, need to remove clothes over waist for measurements so somewhat inconvenient for adolescents. It also varies with changes of body shape during puberty. In our study Cut-off value of neck circumference for predicting overweight in boys and girls were 30.1 cm and 29.65 cm respectively which was nearly similar to study done by Lipilekha Patnaik et al[14] (cut-off

Table 1: Correlation of BMI with Neck Circumference

Age group	Correlation of BMI with Neck Circumference								
	Male			Female			Total		
	N	r value (pearson)	p value	N	r value (pearson)	p value	N	r value (pearson)	p value
9-10 year	27	0.763	<0.00001	15	0.857	0.00004	42	0.796	<0.00001
10-11 year	76	0.815	<0.00001	67	0.830	<0.00001	143	0.809	<0.00001
11-12 year	95	0.684	<0.00001	80	0.741	<0.00001	175	0.629	<0.00001
12-13 year	103	0.753	<0.00001	69	0.754	<0.00001	172	0.739	<0.00001
13-14 year	76	0.670	<0.00001	73	0.617	<0.00001	149	0.629	<0.00001
14-15 year	78	0.636	<0.00001	51	0.453	0.0008	129	0.407	<0.00001
15-16 year	53	0.548	0.0002	25	0.807	<0.00001	78	0.590	<0.00001
16-17 year	16	0.795	0.0002	3	0.879	0.316	19	0.659	0.0021

Table 2: Correlation of BMI with Waist Circumference

Age group	Correlation of BMI with Waist Circumference								
	Male			Female			Total		
	N	r value (pearson)	p value	N	r value (pearson)	p value	N	r value (pearson)	p value
9-10 year	27	0.895	<0.00001	15	0.867	<0.00002	42	0.866	<0.00001
10-11 year	76	0.933	<0.00001	67	0.889	<0.00001	143	0.909	<0.00001
11-12 year	95	0.846	<0.00001	80	0.735	<0.00001	175	0.789	<0.00001
12-13 year	103	0.897	<0.00001	69	0.803	<0.00001	172	0.808	<0.00001
13-14 year	76	0.827	<0.00001	73	0.809	<0.00001	149	0.807	<0.00001
14-15 year	78	0.888	<0.00001	51	0.502	<0.00017	129	0.633	<0.00001
15-16 year	53	0.651	<0.00001	25	0.900	<0.00001	78	0.736	<0.00001
16-17 year	16	0.909	<0.00001	3	0.983	0.118	19	0.887	<0.00001

Table 3: Correlation of BMI with Wrist Circumference

Age group	Correlation of BMI with Wrist Circumference								
	Male			Female			Total		
	N	r value (pearson)	p value	N	r value (pearson)	p value	N	r value (pearson)	p value
9-10 year	27	0.785	<0.00001	15	0.760	<0.00001	42	0.769	<0.00001
10-11 year	76	0.759	<0.00001	67	0.766	<0.00001	143	0.751	<0.00001
11-12 year	95	0.691	<0.00001	80	0.623	<0.00001	175	0.651	<0.00001
12-13 year	103	0.809	<0.00001	69	0.745	<0.00001	172	0.789	<0.00001
13-14 year	76	0.733	<0.00001	73	0.594	<0.00001	149	0.664	<0.00001
14-15 year	78	0.664	<0.00001	51	0.372	0.0071	129	0.424	<0.00001
15-16 year	53	0.427	<0.0014	25	0.696	0.00011	78	0.522	<0.00001
16-17 year	16	0.792	0.0002	3	0.026	0.98	19	0.701	0.0008

Table 4: Correlation of BMI with Mid Upper Arm Circumference

Age group	Correlation of BMI with Mid Upper Arm Circumference								
	Male			Female			Total		
	N	r value (pearson)	p value	N	r value (pearson)	p value	N	r value (pearson)	p value
9-10 year	27	0.929	<0.00001	15	0.876	0.00019	42	0.931	<0.00001
10-11 year	76	0.899	<0.00001	67	0.828	<0.00001	143	0.861	<0.00001
11-12 year	95	0.818	<0.00001	80	0.797	<0.00001	175	0.806	<0.00001
12-13 year	103	0.897	<0.00001	69	0.912	<0.00001	172	0.903	<0.00001
13-14 year	76	0.829	<0.00001	73	0.828	<0.00001	149	0.824	<0.00001
14-15 year	78	0.899	<0.00001	51	0.482	0.00034	129	0.645	<0.00001
15-16 year	53	0.592	0.00002	25	0.886	<0.00001	78	0.732	<0.00001
16-17 year	16	0.912	<0.00001	3	0.879	0.31	19	0.826	0.00001

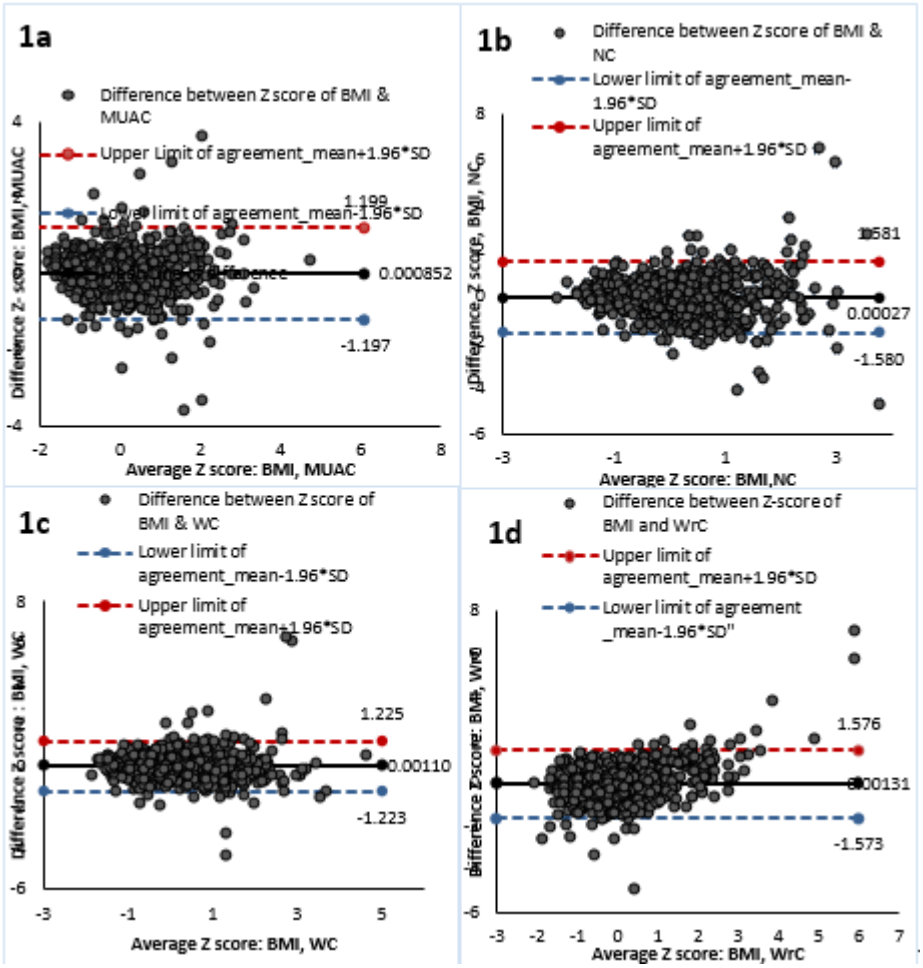

Fig. 1: Bland Altman plot for BMI and Various Circumference; **a:** Bland Altman plot for BMI and Mid Upper Arm Circumference; **b:** Bland Altman plot for BMI and Neck Circumference; **c:** Bland Altman plot for BMI and Waist Circumference; **d:** Bland Altman plot for BMI and Wrist Circumference

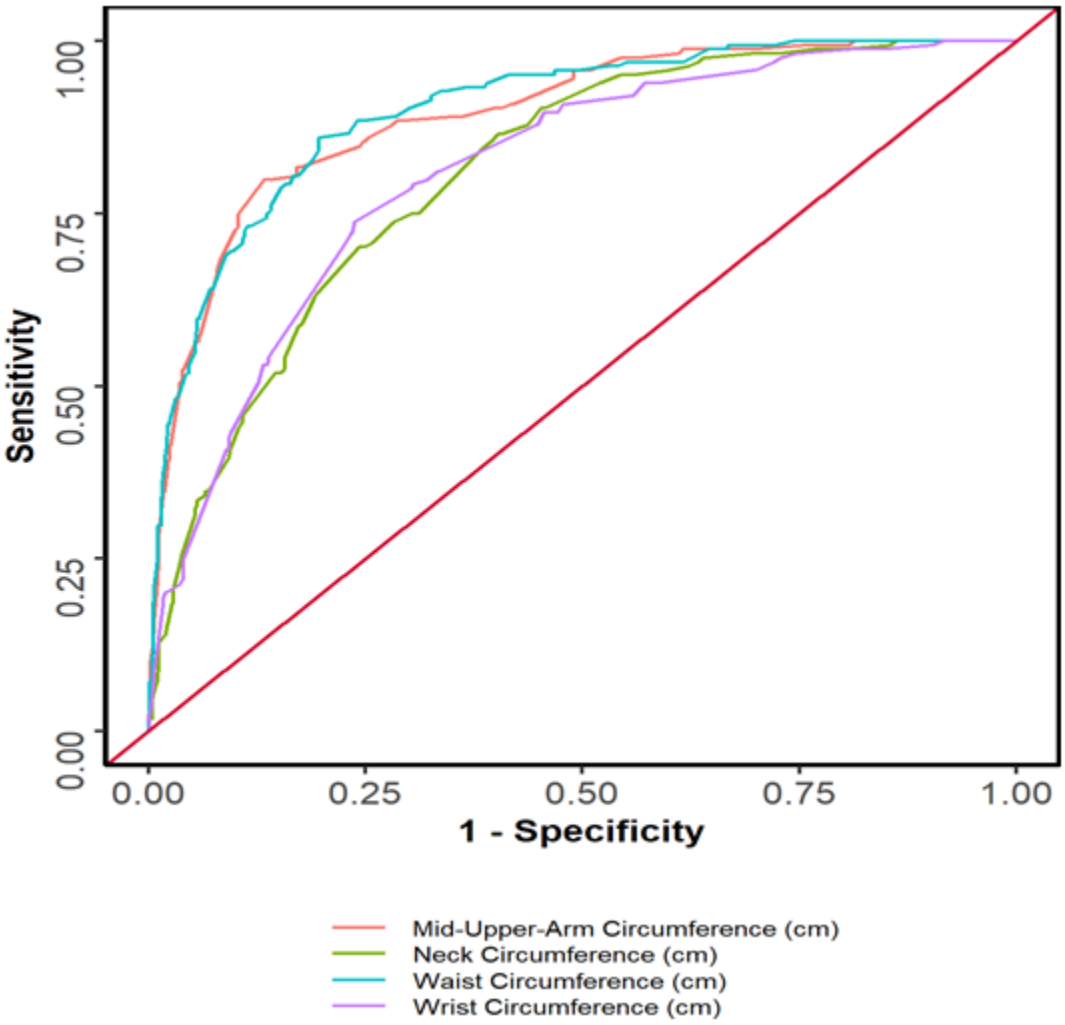

Fig. 2: Suggest ROC Curve of all these Parameters with Comparison to BMI (907 Students)

Table 5: Comparison of the Diagnostic Performance of Various Predictors in Predicting High BMI vs Controls (in Gender: Male & Female) (n=524 for Male) (n=383 for Female)

Predictor	AUROC	P	Cut off (cm)	Sensitivity	Specificity
Neck Circumference (male)	0.800	<0.001	30.1	71.3 %	73.5 %
Neck Circumference (female)	0.828	<0.001	28.65	82.5 %	67.2 %
Waist Circumference (male)	0.894	<0.001	65.15	89.1 %	77.5 %
Waist Circumference (female)	0.909	<0.001	65.15	81.0 %	84.4 %
Wrist Circumference (male)	0.810	<0.001	14.55	76.2 %	71.6 %
Wrist Circumference (female)	0.812	<0.001	14.55	69.8 %	82.5 %
Mid-Upper-Arm Circumference (male)	0.897	<0.001	22.9	82.2 %	85.1 %
Mid-Upper-Arm Circumference (female)	0.887	<0.001	22.9	76.2 %	88.8 %

of neck circumference, for boys: 30.75 cm and for girls: 29.75 cm). Cut off for waist circumference for predicting overweight in our study was 65.15 cm in both boys and girls as compared to 70.75 cm for boys and 69.25 cm for girls in study of Lipilekha Patnaik et al.[14] Difference in this cut off may be due to difference in ethnicity which affects central fat deposition.

In the total male group MUAC had more AUROC than other 3 parameters. Study done by Muhammad Asif et al,[15] Madhur Jaiswal et al[16] also concluded that MUAC also could be used for screening test for obesity and overweight. Cut off for MUAC in our study was 22.9 cm for boys and girls as compared to 16.76-22.73 cm in boys and 16.38-20.57 cm in girls in study of Muhammad Asif et al,[15] and 23 cm and 23.3 cm respectively in boys and girls for age group 10-14 years in study of Madhur Jaiswal et al.[16]

In the present study, AUROC of wrist was low as compared to other parameters but its value was more than 0.8 indicating that it can be used for screening tests. This was supported by study done V. Khadilkar et al in which correlation of wrist circumference with fat percentage was weaker but its prediction for obesity related complications like insulin resistance and hypertension was better.[17] In present study cut-off for wrist circumference was 14.55 cm for boys and girls which was fall in a range of study done by Gita shafiee et al.[18] Gita shafiee et al have done a study for wrist circumference as a predictor of obesity and overweight and have concluded that wrist circumference was an useful index for assessing excess weight in pediatric age group and cut off for male for prediction overweight was 13.95 cm-17.25 cm and for females 13.75 cm-15.85 cm.

We found different cut off for each parameter for predicting overweight with their sensitivity and specificity. In the group of total students, total male and total female Mid upper arm circumference was best parameter in term of specificity while neck circumference was more sensitive in total students and in group of total female students but in total male students, waist circumference was more sensitive than other. This gender discrepancy may be due to difference in fat deposition in male and female due to difference of body composition, sex hormone, distribution of adipose tissue and activity intensity between male and female.[19]

Even though present study has some limitations like done in a single center but it suggests Simple anthropometric parameters like neck circumference, waist circumference, wrist circumference, and mid upper arm circumference can also be used as a screening tool to identify high risk groups.

Based on the findings of this study, we recommended that a large multicentric study population based study should be performed to determine a normogram and percentiles of neck circumference, waist circumference, mid upper arm circumference and wrist circumference in different age groups for male and female.

6. Conclusion

Obesity/overweight is a growing health problem in adolescents. Early recognition is stepping stone to prevent hazards of it. Neck circumference, waist circumference, mid upper arm circumference and wrist circumference are quick, easy, convenient and valid parameters to use as a screening tool for overweight and obesity.

7. Conflict of Interest

None.

8. Funding of Sources

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