Neck Circumference as A Screening Tool to Predict Obesity: A Cross Sectional Study in Coastal Karnataka, India

Shyamsundar Shreedhar[1], Prashant M Naik[2], Geeta[3], Naveenkumar G Havale[4], Manjula MN[5]

[1,2,3,4,5]Karwar Institute of Medical Sciences, Karwar, Karnataka, India

ABSTRACT

Background: BMI is commonly used to classify obesity in adults. WC and WHR are considered as acceptable measures of obesity. However in community settings these can be a time-consuming method. Instead, Neck circumference (NC) can be used to screen for obesity.

Methodology: A cross sectional study among 310 study participants in rural field practice area of Karwar Medical College. Data was collected using pre designed semi structured questionnaire and anthropometric measurements as per standard guidelines. Pearson's correlation coefficient was used to assess correlation. NC cut off values were obtained from ROC.

Results: In our study, the correlation of NC with BMI was highly correlated among both males(r=0.529), and females (r=0.565). Kappa statistics depicted moderate agreement with BMI males (κ = 0.512); females (κ = 0.496) and NC. The cut-off values obtained for NC using ROC curve for males (35.5cm) and females (31.5cm) were statically significant associated in comparison to BMI to determine obesity in both males ($\chi 2$ = 58.57, and females ($\chi 2$ = 21.54).

Conclusion: This study concluded that men with NC ≥ 35.5 cm and females with NC ≥ 31.5 cm are to be considered obese.

Key words: Neck circumference, BMI, obesity, ROC

INTRODUCTION

Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health. More than 1 billion people (close to 650 million adults) worldwide are obese and this number is increasing in an alarming rate.[1] Obesity is a disease of public health importance impacting most body systems. It leads to a range of noncommunicable diseases (NCDs), such as type 2 diabetes, cardiovascular disease, hypertension and stroke, various forms of cancer, as well as mental health issues. People with obesity are also three times more likely to be hospitalized for COVID-19.[1]

As per the NFHS-5 data, the prevalence of overweight/obesity among men and women has doubled in the last two decades from 1998-99 to 2019-21 in India.[2] The prevalence of overweight or obesity among man and women in rural areas of Karnataka is 25.0% and 25.6% respectively.[2]

Body mass index (BMI) is commonly used to classify overweight and obesity in adults. Others measurements such as waist circumference (WC), waist-to-hip ratio (WHR), and body fat percentage are considered as acceptable measures of adult body fat mass and obesity. However, in community settings these can be a time-consuming method. Instead, Neck circumference (NC) can be used to screen for overweight and obesity. Since it is low cost and easy to measure, may be well-accepted in the community settings.

In this study, we aimed to study NC as a screening tool to predict obesity and its correlation with other anthropometric measurements in rural area of coastal Karnataka.

METHODOLOGY

This was a community based cross sectional study conducted from January 2022 to March 2022. Sample size was calculated using the formula $n = Z_{\alpha/2}^2 \, pq \, /e^2$ where 'p' was the percentage of overweight or obesity. According to NFHS-5 Karnataka state fact sheet data, the prevalence of overweight or obesity among man and women in rural areas is 25.0% and 25.6% respectively.[2] standard normal deviate ($Z_{\alpha/2}$) at 5% i.e., 1.96 and allowable error (e) of 10% was considered and the sample size hence calculated was 310.

The study was conducted in Chendia-rural field practice area of community medicine of department, karwar institute of medical sciences in coastal Karnataka. Institutional ethical committee permission was taken before the start of the study. The rural field practice area Chendia is located on either side of national highway 63 with houses being divided in 6 areas and each area was equally represented in total sample size. In each area a landmark location like a school or temple was selected and from there a direction was randomly chosen for that day for selecting the houses. The first house was randomly selected and then the remaining houses were selected on alternate basis on either side of the road till the target of that day was met. When the interviewers visited the house, all individuals in that family aged 18 years and above were assessed for eligibility. Individuals who had history of thyroid disorders and those who refused to be part of the study were excluded. As per clinical neck examination method[3] individuals' neck was examined by interviewers for any thyroid enlargement and those who had thyroid enlargement were also excluded. Individuals who fitted to our inclusion criteria were explained the objectives of study. They were interviewed after obtaining written informed consent. This method was followed till our total sample size was met. Data regarding socio demographic characteristics and reported comorbidities was collected in a semi-structured questionnaire from the study participants. Physical examination was done and measurements such as height, weight, hip, waist and neck circumference were measured using standardized methods.

Anthropometric measurements

i) **Weight:** weight of the individual was measured without any footwear and minimal clothing to the nearest 0.1 kilogram using a standard portable weighing machine and the scale was zeroed before each session.[4]

ii) **Height**: height of the individual was measured in the standing position without any footwear, standing on the flat surface against wall, with weight evenly distributed on both feet, heel together, and the head positioned so that line of vision will be perpendicular to the body. Height was recorded in centimetre to the nearest 0.5 cm.[4]

iii) **Waist circumference**: Individual stands with arms at the sides, feet positioned close together and weight evenly distributed across the feet. Waist circumference was measured at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest. It was measured at the end of a normal expiration.[5]

iv) **Hip circumference**: Individual stands with arms at the sides, feet positioned close together and weight evenly distributed across the feet. Hip circumference was measured around the widest portion of the buttocks.[5]

v) **Neck circumference (NC):** Neck circumference was measured in the midway of the neck, between mid-cervical spine and mid-anterior neck, to within 1 mm, with measuring tape calibrated. In men with a laryngeal prominence (Adam's apple), it was measured just below the laryngeal prominence.

All circumferences were taken with tape snug around the body, but not pulled tight that it was constricting. Non-stretchable tape was used to take all measurements.

Definitions and classifications

a) **Waist circumference**- Waist circumference of more than 90 cm in male and 80 cm in females is the cut off for abdominal obesity.[5]

b) **Waist Hip Ratio (WHR)** = Waist circumference (cm) ÷ Hip circumference (cm)

WHR more than 0.9 will be considered abnormal for males and more than 0.85 will be considered to be abnormal for females.[5]

c) **Body Mass Index (BMI)**=Weight(kg)/Height (m)^2

Body Mass Index was considered as the standard for defining obesity and overweight. Modified BMI classification for Asian population was used. BMI of 18.5-22.99 kg/m^2 was considered normal. BMI of 23-24.99 kg/m2 was categorized as overweight and BMI more than or equal to 25kg/ m^2 was defined as obese.[6]

Analysis: Data was entered, cleaned, coded and analyzed using Epi-info 7.2 version software. Results were expressed in frequencies and proportions with 95% confidence interval. Statistical tests like Pearson's correlation coefficient were used to assess correlation. Neck circumference cut off values were obtained from Receiver Operating Characteristic (ROC) curve.

RESULTS

Out of 310 study participants, 223 were males and 87 were females. Majority of them were in the age

group of 21 to 40 years. Mean age of male partici-pants was 37.6 ± 14.8 years and for females 43.7 ±16.3 years. In the present study mean BMI for males was 23.16 ± 3.97 and for females 24.1 ± 4.7, mean waist circumference for males was 85.61 ± 9.98cms and for females 86.99 ± 11.45cms, mean waist-hip ratio (WHR) for males was 0.90 ± 0.05 and for fe-males 0.9 ± 0.06 and mean neck circumference for males was 35.92 ± 3.89cms and for females 32.23 ± 3.04cms.

As per Pearson's correlation analysis, in males, the correlation of neck circumference with WHR, waist circumference and BMI was weakly(r=0.333), highly correlated (r=0.768) (r=0.529) respectively. In fe-males, the correlation of neck circumference with WHR, waist circumference and BMI was weakly (r=0.229) and highly correlated (r=0.588), (r=0.565) respectively. (Table:3)

Kappa statistics depicted moderate agreement with BMI [males (κ = 0.512) (P < 0.001); females (κ = 0.496) (P < 0.001)] and NC in the study population.

Table 1: Socio demographic characteristics (n=310)

Characteristics	Participants (%)
Age (Years)	
<20	7 (2.3)
21 - 30	99 (31.9)
31 - 40	73 (23.5)
41 - 50	52 (16.8)
51 - 60	41 (13.2)
> 61	38 (12.3)
Gender	
Male	223 (71.9)
Female	87 (28.1)

Table 2: Anthropometric Measurements

Anthropometric Measurements	Males (223) Mean ± SD	Females (87) Mean ± SD	Total (310) Mean ± SD
Height (cm)	167.60 ± 6.89	152.23 ± 7.13	163.28 ± 9.80
Weight (Kgs)	65.35 ± 13.26	55.9 ± 11.8	62.70 ± 13.54
BMI (kg/m^2)	23.16 ± 3.97	24.1 ± 4.7	23.42 ± 4.20
Waist Circumference (cm)	85.61 ± 9.98	86.99 ± 11.45	86.0 ± 10.41
Hip Circumference (cm)	95.06 ± 9.34	96.64 ± 10.59	95.5 ± 9.72
Waist-Hip Ratio (WHR)	0.90 ± 0.05	0.9 ± 0.06	0.90 ± 0.06
Neck Circumference (cm)	35.92 ± 3.89	32.23 ± 3.04	34.89 ± 4.02

Table 3: Pearson's correlation coefficient between NC and other parameters

Anthropometric Measurements	Males (223)		Females (87)	
	r	p-value	r	p-value
Age (years)	0.228	p = 0.001	0.174	p = 0.108
Height (cm)	0.243	p < 0.001	0.359	p = 0.001
Weight (Kgs)	0.533	p < 0.001	0.682	p < 0.001
BMI (kg/m^2)	0.529	p < 0.001	0.565	p < 0.001
Waist Circumference (cm)	0.768	p < 0.001	0.588	p < 0.001
Hip Circumference (cm)	0.724	p < 0.001	0.57	p < 0.001
Waist-Hip Ratio (WHR)	0.333	p < 0.001	0.229	p = 0.033[
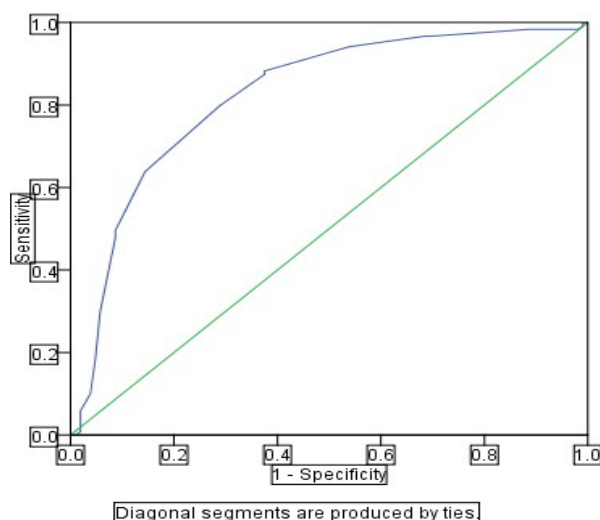
AUC (95% C.I) = 0.822 (0.765 – 0.879) with S.E = 0.029 & Significance, P < 0.001

Figure 1: ROC curve for NC in Males

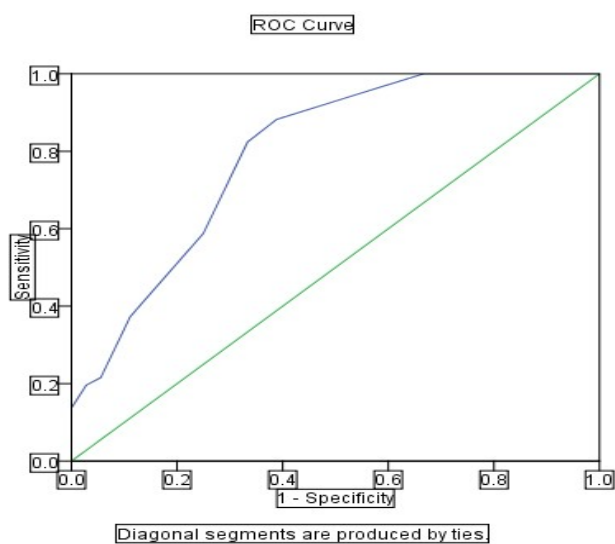## Table 4A: Comparison between NC and BMI in Males

BMI	Neck Circumference		Total
	≥35.5 cm	<35.5 cm	
Obese	95 (79.8)	24(20.2)	119(100)
Not Obese	30(28.8)	74(71.2)	104(100)
Total	125(56.1)	98(43.9)	223(100)

χ^2 = 58.57, p< 0.001, Sensitivity79.83%, Specificity71.15%, Posi-tive Predictive Value: 76%, Negative Predictive Value: 75.51%, Ac-curacy: 75.78%

Using Receiver Operating Characteristic (ROC) curve analysis, the neck circumference cut-off for males was 35.5 cm having sensitivity 79.83%, specificity 71.15%, positive predictive value 76%, negative pre-dictive value 75.51% and accuracy 75.78% with area under curve (AUC) (95% C.I) = 0.822 with s.e=0.029. similarly ROC curve analysis, the neck circumference cut-off for females was 31.5 cm having sensitivity 82.40%, specificity 66.70%, positive predictive value

77.80%, negative predictive value 72.80% and accuracy 75.90% with AUC (95% C.I) = 0.794 with s.e=0.05.AUC was slightly more in males in comparison to females.

The cut-off values obtained for neck circumference using ROC curve for males (35.5cm) and females (31.5cm) were statically significant associated in comparison to BMI to determine obesity in both males ($\chi2$ = 58.57, p < 0.001) and females ($\chi2$ = 21.54, p < 0.001). (Fig:1,2 and Table: 4A,4B)

AUC (95% C.I) = 0.794 (0.696 – 0.893) with S.E = 0.05 & Significance, P < 0.001

Fig 1: ROC curve for NC in Females

Table 4B: Comparison between NC and BMI in Females

BMI	Neck Circumference		Total
	≥ 31.5 cm	<31.5 cm	
Obese	42(82.4)	9 (17.6)	51(100)
Not Obese	12(33.3)	24 (66.7)	36 (100)
Total	54(62.1)	33 (37.9)	87(100)

χ^2= 21.54 p <0.001, Sensitivity82.40%, Specificity66.70%, Positive Predictive Value:77.80%, Negative Predictive Value:72.80%, Accuracy: 75.90%

DISCUSSION

Obesity once considered a problem only in high-income countries, is now dramatically on the rise in low- and middle-income countries, particularly in urban settings. It is a major risk factors for a number of chronic diseases, including cardiovascular diseases such as heart disease and stroke, which are the leading causes of death worldwide.[7]

BMI is generally considered as standard to classify overweight and obesity in adults. WHR, WC and percentage of body fat are also accepted indicators of body fat mass. However, BMI is not perfect because it is only dependant on height and weight and measuring these in community settings can be time consum-

ing and also it has to be calculated which again is a drawback.[8] But in a country like India, it can be particularly challenging to measure these parameters precisely, as per the standardized methods among women due to cultural inhibitions. Many studies have suggested that NC can be an independent correlate of metabolic risk factors.[9-12] NC can be a simpler tool which can be used to screen for overweight and obesity. Since it is low cost and easy to measure, it may be well-accepted in the community settings also. Our study has shown a strong association between NC and BMI for males and female study participants.

Upper body obesity is associated with insulin resistance, hypertriglyceridemia, diabetes and furthermore increases the risk for metabolic complications.[13] Preis SR et al.[14] examined the association between neck circumference and cardiometabolic risk factors among participants in the Framingham Heart Study. The study demonstrated that neck circumference, as a proxy of upper-body subcutaneous fat, is a novel, discrete, and pathogenic fat depot both independent of and synergistic with visceral adipose tissue (VAT). It concluded that Neck circumference is associated with CVD risk factors even after adjustment for VAT and BMI.

In the present study, an attempt was made to find the neck circumference cut-offs for males and females which can be used as an alternate to BMI. In our study, 310 participants were involved, mean age of male participants was 37.6 ± 14.8 years and for females 43.7 ±16.3 years. The anthropometric measurements like BMI, waist circumference, WHR, neck circumference observed in this study were similar to finds by Sanjana SN et al.[15] neck circumference: a valid anthropometric tool, Dudeja V et al.[16] body fat and BMI in Asian Indians, Patnaik, et al.[17] neck and waist circumference as anthropometric measures of overweight/obesity.

In our study we found that correlation between neck circumference with WHR, BMI and waist circumference was weak, moderate and highly correlated in males, whereas they were weak and highly correlated in females. In a cross-sectional study by Sunil Kumar et al.[18] in 2009, carried out among 300 patients admitted in a rural hospital in Wardha, in both men and women, BMI correlated positively with NC (Corr. Coeff = 0.59, p < 0.01) and weight (Corr. Coeff = 0.60, p <0.01); NC (Corr. Coeff = 0.74, p < 0.01) and weight (Corr. Coeff = 0.82, p < 0.01), respectively. NC ≥ 38 cm for men and ≥ 34.7 cm for women were the best cut-off points for determining subjects with overweight.

More recently, in 2019, Sanjana SN et al.[15] conducted a study among urban slum population in Davangere consisting of 512 study participants and concluded that males with NC ≥36 cm and females with NC ≥ 29 cm are to be considered obese. In a study conducted in Maharashtra by Patil C et al.[19] with 479 study subjects in 2013, it was observed that the cut off of 36.50cms in males and 32.50cms in females will help

to screen the population of Asian Indian origin. The sensitivity of this screening test for this cut off was 84.85% and 73.68% in males and females respectively. The findings of both these studies are similar to the results of our study.

M. A. N. Saad et al.[13] in their Brazilian study found NC was positively correlated with WC (r = 0.69 and r = 0.66), BMI (r = 0.71 and r = 0.72) and WHR (r = 0.45 and r = 0.27) in aged men and women, respectively. Preis SR et al.[14] in their Framingham heart study concluded that NC was strongly correlated with WC [men (r=0.75) and women (r=0.78)]and BMI [men (r=0.79) and women (r=0.80)]. Sanjana SN et al.[15]in their study have found that Neck circumference was positively correlating with Waist circumference (r = 0.372), Hip circumference (r = 0.110) and BMI (r = 0.313). Patnaik L et al.[17] 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. Sunil Kumar, et al.[18] in their NC as a predictor of obesity have found that in both men(r=0.59) and women (r=0.74) BMI correlated positively with NC.

Patil C et al.[19] have found that in males, the correlation of neck circumference with BMI and waist circumferencewas weak (r=0.494) and moderate (r=0.556) correlation respectively whereas in fe-males the correlationof neck circumference was moderate with BMI (r=0.590) and waist circumference(r=0.614). Tantawy SA et al.[20] in their study have concluded that weak, positive correlation between neck circumference and BMI. Alfadhli et al[21] in their Saudi Arabia study found positive associations between NC and WC (r=0.7 and r=0.5), BMI (r=0.5 and r=0.5) in males and females respectively.

Aswathappa et al.[22] Neck circumference and diabetes have found that statistically significant positive correlation between NC with BMI(r=0.768) and WC(r=0.708) among non-diabetic study participants. Verma, et al.[23] Neck circumference: Independent predictor for obesity found that in both the genders, NC was positively correlated with BMI (men, r=0.670; women, r=0.564), WC (men, r=0.598; women, r=0.615) and WHR (men, r=0.380; women, r=0.022). Joshipura K et al.[24] in their neck circumference may be a better alternative study found that NC was significantly correlated with BMI (r=0.66).and WC (r=0.64). Yang GR et al.[25] in their Beijing study NC correlated positively with BMI and WC in both men and women. Özkaya I et al.[26] in their study on Turkish university students found that in both males and females NC revealed a positive correlation with BMI (men, r=0.684; women, r=0.482), WC (men, r=0.686; women, r=0.479), and WHR (men, r=0.646; women, r=0.246).

Table 5: Cut-off values for NC among different studies

	Our Study	Sanjana SN et al[15]	Sunil K et al[18]	Patil C et al[19]	Alfadhli et al[21]	VermaM et al[23]	Qureshi NK et al[27]
Sample size	M:223 F:87	M:256 F:256	M:120 F:83	M:191 F:288	M:370 F:415	M:540 F:540	M:496 F:375
NC cut-off for males (cm)	≥ 35.5	≥ 36	≥38	≥36.5	≥39.25	≥36.55	≥35.25
AUC	0.822	0.856	0.89	0.800	0.86	0.822	0.83
Sensitivity	79.83%	83.3%	81.8%	84.85%	89%	63.2%	-
Specificity	71.15%	84.4%	84.4%	66.40%	71%	84.8%	-
Accuracy	75.78%	-	-	72.7%	-	-	-
NC cut-off for females (cm)	≥ 31.5	≥ 29	≥34.7	≥32.5	≥34.75	≥34.05	≥34.25
AUC	0.794	0.747	0.91	0.800	0.77	0.873	0.76
Sensitivity	82.40%	65.6%	76.9%	73.64%	80%	66.9%	-
Specificity	66.70%	94.8%	94.2%	65.17%	65%	86.6%	-
Accuracy	75.90%	-	-	68.4%	-	-	-

Table 5 shows the comparisons among different studieson cut-off value of NC for screening obesity. For males the NC cut-off ranged from 35.25 cm to 39.25 cm with AUC 0.800 to 0.89. Similarly for females the NC cut-off ranged from 29 cm to 34.75 cm with AUC 0.747 to 0.91. As various studies have shown their cut-off of NC for males and females, there is no fixed cut-off of NC for screening obesity as an alternate to BMI. Hence a larger multicentre study might recommend a better cut-off of NC for males and females.

CONCLUSION

Neck circumference may be used as a simple and less time-consuming screening tool to identify individu-als who are overweight and obese. This study concluded that men with NC ≥ 35.5 cm and females with NC ≥ 31.5 cm are to be considered obese. The sensitivity of this screening test for this cut off was 79.83% and 82.4% in males and females respectively.

LIMITATION OF THE STUDY

Since our study was conducted in a small geographical area community-based study, results may over-estimate the true correlation between NC and obesity. Another limitation is that since NC is a proxy for upper-body fat; we did not have radiographic measures to directly quantify this fat deposition.

ACKNOWLEDGEMENT

REFERENCES

1. World Health Organization;World Obesity Day 2022 – Accel-erating action to stop obesity Available at: https://www.who.int/news/item/04-03-2022-world-obesity-day-2022-accelerating-action-to-stop-obesity Assessed on 15/03/2022, 12.00pm.

2. Government of India. Ministry of Health and Family Welfare. National Family Health Survey-5 data. Available at: http://rchiips.org/nfhs/factsheet_NFHS-5.shtml Assessed on 15/03/2022, 12.30pm.

3. J Alastair Innes, Anna R Dover, Karen Fairhurst. Macleod's Clinical Examination, 14th edition. London : Elsevier ; 2018. P 189-90, 194-195.

4. (WHO TR 854) Report of a WHO Expert Committee. Physical status: The use and interpretation of anthropometry WHO Technical Report Series 854.1995.

5. World Health Organization. Waist circumference and waist-hip ratio: report of a WHO expert consultation. Geneva: World Health Organization (WHO); 2008 December 39p. ISBN9789241501491.

6. Misra A, Chowbey P, Makkar BM, Vikram NK, Wasir JS, Chadha D, Joshi SR, Sadikot S, Gupta R, Gulati S, Munjal YP. Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management.JAssoc Physicians India. 2009 Feb;57:163-70. Review. PubMed PMID: 19582986.[PubMed]).

7. World Health Organization; Home/Newsroom/Fact sheets/Detail/Obesity and overweight Available at:https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight Assessed on 15/03/2022, 1.30pm).

8. World Health Organization; Home/Health topics/Obesity Available at: https://www.who.int/health-topics/obesity#tab=tab_2 Assessed on 15/03/2022, 1.00pm.

9. Ben-Noun L, Laor A 2003 Relationship of neck circumference to cardiovascular risk factors. Obes Res 11:226–231.

10. Ben-Noun LL, Laor A 2006 Relationship between changes in neck circumference and cardiovascular risk factors. Exp Clin Cardol 11:14–20.

11. Freedman DS, Rimm AA 1989 The relation of body fat distri-bution, as assessed by six girth measurements, to diabetes mellitus in women. Am J Public Health 79:715–720.

12. Laakso M, Matilainen V, Keina¨nen-Kiukaanniemi S 2002 Asso-ciation of neck circumference with insulin resistance-related factors. Int J Obes Relat Metab Disord 26:873–875.

13. Saad MAN, Rosa MLG, Lima GB, Antunes da Cruz R Filho. Can neck circumference predict insulin resistance in older people? A cross-sectional study at primary care in Brazil. Cad SaudePublica. 2017 Aug 21;33(8):e00060916. DOI: 10.1590/0102-311X00060916.

14. Preis SR, Massaro JM, Hoffmann U, D'Agostino RB Sr, Levy D, Robins SJ, Meigs JB, Vasan RS, O'Donnell CJ, Fox CS. Neck cir-cumference as a novel measure of cardiometabolic risk: the Framingham Heart study. J ClinEndocrinolMetab. 2010 Aug;95(8):3701-10. DOI: 10.1210/jc.2009-1779.

15. Sanjana SN, Davalagi S, Huchappa RK. Neck Circumference: A valid anthropometric tool to predict Obesity in Adults of Da-vanagere, South India. Indian J Comm Health. 2019;31(4):457-463. DOI: https://doi.org/10.47203/IJCH.2019.v31i04.007.

16. Dudeja V, Misra A, Pandey RM, Devina G, Kumar G, Vikram NK. BMI does not accurately predict overweight in Asian Indians in northern India. Br J Nutr. 2001 Jul;86(1):105-12. DOI: 10.1079/bjn2001382.

17. Patnaik L, Pattnaik S, Rao EV, Sahu T. Validating Neck Circum-ference and Waist Circumference as Anthropometric Measures of Overweight/Obesity in Adolescents. Indian Pedi-atr. 2017 May 15;54(5):377-380. DOI: 10.1007/s13312-017-1110-6.

18. Sunil K, Gupta A, Jain S Neck circumference as a predictor of obesity and overweight in rural central India. Int. J. Med. Pub-lic health 2012; 2(1): 62-66 DOI: 10.5530/ijmedph.2.1.11.

19. Patil C, Deshmukh J, Yadav S, Patil S, Sheikh A Neck circumfer-ence: A novel anthropometric tool for screening obesity in adults International Journal of Collaborative Research on In-ternal Medicine & Public Health 2017; 9(7): 711-720.

20. Tantawy S, Kamel DM, Alsayed N, Rajab E, Abdelbasset WK Correlation between body mass index, neck circumference, and waist-hip ratio as indicators of obesity among a cohort of adolescent in Bahrain A preliminary cross-sectional study Medicine: 2020 Apr;99(17):e19950. DOI: 10.1097/MD.0000000000019950.

21. Alfadhli EM, Alaa AS, Basma NZ, Mohammed AM, Reem FA, Ta-fani ST, Hanan AH Neck circumference as a marker of obesity and a predictor of cardiometabolic risk among Saudi subjects Saudi Med J 2017; Vol. 38 (12): 1219-1223 DOI: 10.15537/smj.2017.12.20926.

22. Aswathappa J, Garg S, Kutty K, Shankar V. Neck circumference as an anthropometric measure of obesity in diabetics. N Am J Med Sci. 2013 Jan;5(1):28-31. DOI: 10.4103/1947-2714.106188.

23. Verma M, Rajput M, Sahoo SS, Kaur N. Neck Circumference: Independent Predictor for Overweight and Obesity in Adult Population. Indian J Community Med. 2017 Oct-Dec;42(4):209-213. DOI: 10.4103/ijcm.IJCM_196_16.

24. Joshipura K, Muñoz-Torres F, Vergara J, Palacios C, Pérez CM. Neck Circumference May Be a Better Alternative to Standard Anthropometric Measures. J Diabetes Res. 2016;2016:6058916. DOI: 10.1155/2016/6058916.

25. Yang GR, Yuan SY, Fu HJ, Wan G, Zhu LX, Bu XL, Zhang JD, Du XP, Li YL, Ji Y, Gu XN, Li Y. Neck circumference positively relat-ed with central obesity, overweight, and metabolic syndrome in Chinese subjects with type 2 diabetes: Beijing Community Diabetes Study 4. Diabetes Care. 2010 Nov;33(11):2465-7. DOI: 10.2337/dc10-0798.

26. Özkaya İ, Tunçkale A. Neck Circumference Positively Related with Central Obesity and Overweight in Turkish University Students: A Preliminary Study. Cent Eur J Public Health. 2016 Jun;24(2):91-4. DOI: 10.21101/cejph.a4555.

27. Qureshi NK, Hossain T, Hassan MI, Akter N, Rahman MM, Sul-tana MM, et al. Neck circumference as a marker of overweight and obesity and cutoff values for Bangladeshi adults. Indian J EndocrMetab 2017;21:803-8. DOI: 10.4103/ijem.IJEM_196_17.