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Predictive superiority of abdominal obesity measures over body mass index in Indian hypertensive adults

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ABSTRACT

Background: Obesity has emerged as an epidemic and is known to be associated with multiple co-morbidities, contributing to increased morbidity and mortality. Body-mass index (BMI) has been traditionally used to assess obesity in an individual but abdominal obesity markers are being claimed to have a stronger association with adverse cardiovascular outcome as compared to BMI. However, there are only a few studies that have evaluated these indices in Asian Indians. **Aims and Objectives:** The study was conducted to compare BMI and waist measurement based indices among hypertensive adults and their association with adverse cardiovascular outcomes. The secondary objectives were to determine any gender-based differences among anthropometric indices and improved predictability on adding waist-based indices to BMI. **Materials and Methods:** An observational study was conducted to analyse association of anthropometric indices such as BMI, A body shape index (ABSI), Waist–hip ratio (WHR), Waist-to-height ratio (WHtR), Lean body mass-to-weight ratio, and Waist circumference (WC), with risk of cerebrovascular accidents (CVA) and coronary artery disease (CAD) in Indian hypertensive adults. **Results:** In total, 400 participants were included and female subjects were noted to have higher prevalence of obesity in our study population. Only 33.25% patients had BMI in recommended range and the numbers were even lower for WHtR and WHR. BMI and ABSI were found to have a weak association with development of co-morbidities while measures of abdominal obesity such as WHR, WC, and WHtR were found to have consistently strong association with CVA and CAD with high sensitivity and negative predictive values. **Conclusion:** More accurate markers of abdominal obesity can help in better assessment of cardiovascular risk among high-risk population to improve the overall outcome. Easy to use, outpatient-based markers such as WC, WHR, and WHtR appear to be better than BMI in risk assessment.

Key words: Hypertension; Indian; Body-mass index; Waist-hip ratio; Waist circumference; Co-morbidities; Cerebrovascular accidents; Coronary artery disease; Abdominal obesity

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INTRODUCTION

Overweight and obesity have surged in prevalence recently,[1] correlating with multisystem morbidities such as metabolic syndrome, diabetes mellitus, hypertension, and increased mortality.[2] In India, the prevalence of obesity ranges from 11.8% to 31.3%, and central obesity from 16.9% to 36.3%.[3] Contributing factors include lifestyle changes, dietary habits, lack of awareness.[3] This issue is particularly pressing in developing countries where healthcare systems are financially strained,[3] exacerbating cardiovascular morbidity and mortality.[4]

Body mass index (BMI) has been the traditional measure of obesity, predicting adverse cardiovascular outcomes.[4] Waist circumference (WC) is another simple tool to assess abdominal obesity, linked to increased morbidity.[4,5] Abdominal obesity is known to elevate hypertensive

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risk regardless of physical activity.[6] Abdominal obesity indicators are being evaluated for their association with cardiovascular outcomes, including waist-to-height ratio (WHtR), waist-hip ratio (WHR), lean body mass (LBM), LBM-to-weight ratio (LBMW), and A body shape index (ABSI).[7-11] Accurate estimation of obesity and central obesity is crucial, as weight loss improves cardiovascular outcomes.[12,13] New anthropometric indices are proposed as better predictors of central obesity and cardiovascular outcomes.[4-7,9,11,14-18]

Hypertension, affecting nearly 25% of adults over 18 in India, is often poorly controlled.[19] Co-morbidities include metabolic syndrome, diabetes, nephropathy, coronary artery disease (CAD), and cerebrovascular accidents (CVA).[4] The combined risk of obesity and hypertension further worsens cardiovascular outcomes.[2,4] BMI alone appears inadequate compared to other indices.[18,20,21] This study aims to examine various anthropometric indices among hypertensive adults to assess their association with cardiovascular complications.

Aims and objectives

The study was conducted to compare BMI and waist measurement based indices among hypertensive adults and their association with adverse cardiovascular outcomes. The secondary objectives were to determine any gender based differences among anthropometric indices and improved predictability on adding waist-based indices to BMI.

MATERIALS AND METHODS

A retrospective cross-sectional study was conducted among data of hypertensive patients at a tertiary-care centre located in Central India. STROBE checklist for cross-sectional study was followed while designing the study. The study was approved by institutional (L.N. Medical College and research center and J.K. Hospital) ethical committee (Reg no. ECR/1190/INST/MP/2019). Participant anonymity was ensured during data collection and analysis. The study did not require obtaining consent as the design was retrospective and anonymous. The study procedures were in accordance with the guidelines as per Declaration of Helsinki (1964 and further revisions).

Inclusion criteria

All the participants were of Indian origin and aged 18 years and above. The study was carried out on patient records from June to October 2022 and simple random sampling was performed to select hypertensive patients, who had their anthropometric indices measured, to be included in the study. In total, 400 participants were included and their various body characteristics were then measured and documented. Hypertension was diagnosed as per Indian cut-offs: A blood pressure (BP) of ≥140 mmHg or ≥90 mmHg on at least two occasions on different days, or prior treatment with antihypertensive medications at the time of registration irrespective of their BP reading, or ≥160 mmHg systolic or ≥100 mmHg diastolic on a single day with two readings.[19] Various anthropometric indices and obesity indicators were then compared to evaluate their association with CVA and CAD.

Exclusion criteria

Co-existing diabetes mellitus, thyroid disorders, autoimmune disorders, chronic kidney disease and other chronic disorders that may predispose towards CVA and CAD. Records with incomplete anthropometric measurements were also excluded from the study.

Study tools

Data collection was done based on a pre-set proforma which included baseline characteristics, history of co-morbidities and medication, anthropometric measurements such as weight (kg), height (cm), WC, and hip circumference (HC).

Weight was measured using electronic weighing scale to the nearest 0.1 kg and height was measured using a wall mounted scale to the nearest 0.5 cm with the respondents standing without footwear. Body length was measured for bed-ridden CVA patients. Waist and hip measurements were taken using a measuring tape. WC was measured at midpoint between the top of iliac crest and the lower margin of last palpable rib in midaxillary line, the unit used was centimetres.[7] HC was measured, in centimetres, at the largest circumference of the buttocks.[7] Cutoffs for WC were 90 cm in men and 80 cm in women, as per Asian standards.[7,22] Annexure 1 mentions formulas for various anthropometric indices and their cut-off values along with references.[9,10,23,14-17,24-26]

Data were analyzed using SPSS version 20 (IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp) and Microsoft Excel version 2019. Analyses included mean, standard deviation, Pearson's correlation (r), receiver operating curve, linear regression analysis wherever applicable. Statistical significance was set at $P<0.05$.

RESULTS

In total 400 participants were included in the study; all were diagnosed case of hypertension. Of them, 201 (50.25%) were male and 199 (49.75%) were female. The mean age was 59 years (±11.8). In terms of comorbidities, 21 patients had CVA while 16 had CAD.

Mean BMI and WHtR were found to be higher for females as compared to males (Table 1) and both the differences were statistically significant. Mean ABSI and LBMW were found to be lower for females as compared to males (Table 1) and both the comparisons were statistically significant.

Among the included 400 participants, 134 (33.25%) had BMI in recommended range, 41 (10.25%) had WHtR in recommended range, 104 (26%) had normal range WHR, 146 (36.5%) had good or low risk ABSI while 304 (76%) were found to have optimal LBMW as per recommended cut-offs. Only 107 (53%) females had LBMW in the recommended range as opposed to 197 (98%) males (P<0.001, 95% CI: 37.9–52.2).

On analysing various indices and their association with risk of CVA among hypertensive adults, the present study found that BMI and ABSI have weaker association with CVA as compared to WHR, WHtR, WC, and LBMW (Table 2). WC, WHtR and LBMW were noted to be particularly strongly associated with CVA irrespective of gender. Table 2 also shows area under curve (AUC) for respective indices along with standard errors.

Waist measurement-based indices were found to have higher sensitivity as compared to the traditionally used BMI and most of the indices had high negative predictive values (NPV), for the risk of a hypertensive adult developing CVA (Table 2). However, BMI and ABSI showed relatively higher specificity as compared to the waist measurement indices. None of the indices were noted to have a clinically significant positive predictive value (PPV).

On comparing different indices for development of CAD among hypertensive adults, BMI and ABSI were again found to be weaker indicators as compared to other indices. WHtR showed strongest association with CAD risk in the study population. Table 3 shows AUC for respective indices for CAD risk in the study population. Abnormal WHtR was noted to carry a relative risk of 3.38 for development of CAD (P=0.6123, 95% CI: 0.1589–2.9556).

WC, WHR, and WHtR were found to have higher sensitivity and NPV as compared to the traditionally used BMI, for the risk of a hypertensive adult developing CAD (Table 3). However, BMI and ABSI showed relatively higher specificity as compared to WC, WHtR and WHR. None of the indices were noted to have a clinically significant PPV.

LBMW ratio was found to have a stronger association with CVA and CAD for females as compared to males (Table 4).

Simple linear regression analysis was performed to compare BMI and WC with risk of development of CVA and CAD. It revealed that, in general, BMI had a weaker association with adverse cardiovascular outcomes as compared to WC. It was also noted that combining BMI with waist measurement-based indices improves risk prediction (Table 5).

Table 1: Mean values for various anthropometric indices

Parameter	Mean (SD)			
	Total (n=400)	Male (n=201)	Female (n=199)	P-value (95% CI)
BMI	25.2 (4.62)	24.8 (3.89)	25.7 (5.15)	0.0497 (−1.7986–0.0014)
ABSI	0.086 (0.008)	0.087 (0.007)	0.085 (0.009)	0.0162 (−0.0036 to−0.0004)
WHR	0.98 (0.078)			
WHtR	0.57 (0.064)	0.56 (0.056)	0.58 (0.070)	0.0011 (−0.0320 to 0.0080)
LBMW	0.7 (0.093)	0.8 (0.062)	0.7 (0.085)	<0.001 (0.0853–0.1147)

SD: Standard deviation, CI: Confidence interval, BMI: Body mass index, ABSI: A body shape index, WHR: Waist-hip ratio, WHtR: Waist-to-height ratio, LBMW: Lean body mass-to-weight ratio

Table 2: Statistical analyses values for various anthropometric indices for development of CVA among hypertensive adults

Statistical parameter	ABSI	BMI	WHR	WHtR	LBMW	WC
AUC	0.68878	0.714474	0.79897	0.824727	0.827207	0.828496
SE	0.00394	0.231361	0.00469	0.003237	0.00042	0.538677
AUC Comparison (BMI)	P=0.9116	N/A	P=0.7150	P=0.6337	P=0.6261	P=0.8458
Sensitivity	66.67	65.00	95.24	90.48	95.24	90.48
Specificity	33.77	33.42	6.86	10.29	10.34	6.33
PPV	6.66	6.47	6.76	6.67	7.00	5.08
NPV	93.46	93.09	95.31	93.84	96.84	92.31

AUC: Area under curve, SE: Standard error, PPV: Positive predictive value, NPV: Negative predictive value, BMI: Body mass index, ABSI: A body shape index, WHR: Waist-hip ratio, WHtR: Waist-to-height ratio, LBMW: Lean body mass-to-weight ratio, WC: Waist circumference

Table 3: Statistical analyses values for various anthropometric indices for development of CAD among hypertensive adults

Statistical parameter	ABSI	BMI	LBMW	WC	WHR	WHtR
AUC	0.608398	0.71403	0.790249	0.798177	0.800781	0.811621
SE	0.00394	0.231361	0.00042	0.538677	0.00469	0.003237
AUC comparison (BMI)	P=0.6480	N/A	P=0.7418	P=0.8859	P=0.7077	P=0.6732
Sensitivity	81.25	50.00	87.50	100.00	100.00	100.00
Specificity	34.38	32.81	9.95	6.77	7.03	10.62
PPV	4.91	3.01	3.91	4.28	4.29	3.90
NPV	97.78	94.03	95.00	100.00	100.00	100.00

AUC: Area under curve, SE: Standard error, PPV: Positive predictive value, NPV: Negative predictive value, BMI: Body mass index, ABSI: A body shape index, WHR: Waist-hip ratio, WHtR: Waist-to-height ratio, LBMW: Lean body mass index, WC: Waist circumference

Table 4: AUC values for males and females comparing association of LBMW with CVA and CAD

Sex	CVA	CAD	SE
Males	0.803986	0.730392	0.0044
Females	0.873921	0.860256	0.0060
AUC comparison	P<0.001	P<0.001	

AUC: Area under curve, LBMW: Lean body mass index, CVA: Cerebrovascular accident, CAD: Coronary artery disease, SE: Standard error

Table 5: Results of linear regression analysis for BMI versus waist-based indices

Indices	Linear regression analysis results	
	CVA (n=400)	CAD (n=400)
BMI	R^2=0.003, P=0.271	R^2=0.0037, P=0.227
WC	R^2=0.0365, P=0.0021	R^2=0.0091, P=0.3074
BMI+WC	R^2=0.0204, P=0.148	R^2=0.0075, P=0.7042
BMI+WHR	R^2=0.0219, P=0.1199	R^2=0.0123, P=0.4274
BMI+WHtR	R^2=0.0298, P=0.035	R^2=0.0081, P=0.6695

CVA: Cerebrovascular accident, CAD: Coronary artery disease, BMI: Body mass index, WC: Waist circumference, WHR: Waist–hip ratio, WHtR: Waist-to-height ratio

DISCUSSION

This study showed that the females had higher mean BMI and WHtR as compared to males. This can be partially attributed to females having higher fat proportion as compared to males[27] which is further evidenced by lower mean LBM as well as lower body surface area among females. Only half of the females had LBM to weight ratio in the recommended range as opposed to 98% of males. This further emphasizes on females having higher fat percentage or lower muscle mass. This study also observed that only 33% of participants had BMI in the recommended range which is less than half of the estimates for general population. These numbers were further lower for WHtR and WHR. This observation suggests that majority of subjects in our study population were either overweight or obese, this was especially true for female participants. Lower LBM to weight ratio (lean body BMI) is associated with higher cardiovascular risk since it is an indirect indicator of higher fat proportion. Lower LBMW was found to be a stronger predictor of CVA, CAD among female subjects as compared to males. This may suggest that females need to have a tighter control over body fat content to reduce cardiovascular risk. This is particularly important since prevalence of cardiovascular disorders increases with age[28] and central obesity also increases after menopause.[29]

In this study, ABSI and BMI were consistently found to have the weakest association with co-morbidites as compared to WC, WHR, WHtR, and LBMW. Abnormal WC, LBMW, and WHtR were very strongly associated with increased risk of CVA among hypertensive adults. Higher WHtR and WHR were very strongly associated with a higher risk of development of CAD among the study subjects. WC and LBMW were also found to be better predictors than BMI and ABSI. These observations are consistent with the notion that BMI, although most used, is a less accurate measure of obesity and hence a weaker predictor of cardiovascular risk. The current study provides similar evidence for Asian Indian population. The fact that the indices measuring abdominal or central obesity were found to have the strongest association with the comorbidities agrees with the current understanding that abdominal obesity carries a higher risk for cardiovascular morbidity and mortality.[6] These findings agree with some prior studies; however, they were primarily conducted on western populations. More data are needed for Asian population, particularly Asian Indians.

The observation that BMI had weakest association with CVA and CAD among hypertensive adults also supports the postulate that abdominal fat is more strongly associated with cardiovascular outcomes as compared to total body fat.[6]

Anthropometric indices are easy to use and can be performed in a short time on outpatient basis and studies have shown them to be reliable predictors of adverse cardiovascular outcomes in different populations.[4,6,14-17] However, the data are lacking for newer obesity and central obesity indicators amongst Asian Indian population. BMI, WC and WHR have been standardized for Asian population

but the standardization is lacking for LBM, WHtR and ABSI and research is needed to adjust formulae or cutoffs for Asians.

Limitations of the study

The main limitation of this study is lack of a control group which could have further helped in establishing findings of the study. Another limitation is confounding factors such as smoking, tobacco, and alcohol could not be ruled out as they have the potential to add to adverse cardiovascular outcomes. Multiple analyses did not reach statistical significance, possibly due to a relatively small sample size but the difference is clinically important in certain comparisons, nevertheless.

CONCLUSION

Addressing the epidemic of obesity is the need of the hour and it is further important due to its association with adverse cardiovascular outcomes. This makes correct estimation of obesity and abdominal/central obesity very important and hence choosing the appropriate tool. BMI is the most widely used measure but it is probably not the best anthropometric index to predict adverse cardiovascular outcome. The current study suggests that measures for abdominal obesity such as WC, waist–hip ratio, and WHtR are more strongly associated with adverse cardiovascular morbidity and mortality among Indian hypertensive adults. A larger study amongst this ethnic group with a non-hypertensive control group would further help in evaluating this association. These easy to use, out-patient based tools can help in stratifying patients and thereby more aggressive reduction of obesity amongst who are at extra risk for associated comorbidities in high-risk population group which can help in improving overall outcomes.

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REFERENCES

1. World Health Organization. Obesity: Preventing and managing the global epidemic. World Health Organ Tech Rep Ser. 2000;894:1-253.
2. Wang S, Xiang M and Ren J. Associations of overweight and obesity with the risk of cardiovascular disease. Nutr Metab Cardiovasc Dis. 2023;33(4):1235-1242.
3. Ahirwar R and Mondal PR. Prevalence of obesity in India: A systematic review. Diabetes Metab Syndr Clin Res Rev. 2019;13(1):318-321.
https://doi.org/10.1016/j.dsx.2018.08.032
4. Schmitz KH, Hill TR and DuPont JJ. Abdominal adiposity and coronary heart disease in women. JAMA. 2020;324(7):1234-1241.
5. Ashwell M and Gibson S. Waist-to-height ratio as an indicator of "early health risk": Simpler and more predictive than using a "matrix" based on BMI and waist circumference. BMJ Open. 2016;6(3):e010159.
https://doi.org/10.1136/bmjopen-2015-010159
6. Rhee EJ, Cho JH, Kwon H, Lee MK, Kim KW, Park CY, et al. Association between abdominal obesity and increased risk for the development of hypertension regardless of physical activity: A nationwide population-based study. J Clin Hypertens (Greenwich). 2018;20(10):1417-1426.
https://doi.org/10.1111/jch.13389
7. Ng M, Fleming T and Robinson M. Body fat distribution and noncommunicable diseases: Insights from global studies. Nutr Public Health. 2021;35(2):18-22.
8. Medina-Inojosa JR, Somers VK, Thomas RJ, Jean N, Jenkins SM, Gomez-Ibarra SA, et al. Association between adiposity and lean mass with long-term cardiovascular events in patients with coronary artery disease: No paradox. J Am Heart Assoc. 2018;7(10):e007505.
https://doi.org/10.1161/JAHA.117.007505
9. Thomas DM, Bredlau C, Bosy-Westphal A, Müller MJ, Shen W, Gallagher D, et al. Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. Obesity (Silver Spring). 2013;21(11):2264-2271.
https://doi.org/10.1002/oby.20408
10. Shimizu R, Nakanishi N, Ishihara M, Oto J and Kotani J. Utility of lean body mass equations and body mass index for predicting outcomes in critically ill adults with sepsis: A retrospective study. Diseases. 2024;12(2):30.
https://doi.org/10.3390/diseases12020030
11. Hacıağaoğlu N, Öner C, Çetin H and Şimşek EE. Body shape index and cardiovascular risk in individuals with obesity. Cureus. 2022;14(1):e21259.
https://doi.org/10.7759/cureus.21259
12. Cohen JB. Hypertension in obesity and the impact of weight loss. Curr Cardiol Rep. 2017;19(10):98.
https://doi.org/10.1007/s11886-017-0912-4
13. Wilding JP and Jacob S. Cardiovascular outcome trials in obesity: A review. Obes Rev. 2021;22(1):e13112.
https://doi.org/10.1111/obr.13112
14. Krakauer NY and Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. PLoS One. 2012;7(7):e39504.
https://doi.org/10.1371/journal.pone.0039504
15. Ross R, Berentzen T, Bradshaw AJ, Janssen I, Kahn HS, Katzmarzyk PT, et al. Does the relationship between waist circumference morbidity and mortality depend on measurement protocol for waist circumference? Obes Rev. 2008;9(4):312-325.
https://doi.org/10.1111/j.1467-789X.2007.00411.x
16. Misra A, Vikram NK, Gupta R, Pandey RM, Wasir JS and Gupta VP. Waist circumference cutoff points and action levels for Asian Indians for identification of abdominal obesity. Int J Obes (Lond). 2006;30(1):106-111.
https://doi.org/10.1038/sj.ijo.0803111
17. Browning L, Hsieh S and Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0·5 could be a suitable global boundary value. Nutr Res Rev. 2010;23(2):247-269.

https://doi.org/10.1017/S0954422410000144

18. Krakauer NY and Krakauer JC. Untangling waist circumference and hip circumference from body mass index with a body shape index hip index and anthropometric risk indicator. Metab Syndr Relat Disord. 2018;16(4):160-165.
https://doi.org/10.1089/met.2017.0166
19. Kaur P, Kunwar A, Sharma M, Agarwal V, Gupta P, Satheesh K, et al. India hypertension control initiative-hypertension treatment and blood pressure control in a cohort in 24 sentinel site clinics. J Clin Hypertens (Greenwich). 2021;23(4):720-729.
https://doi.org/10.1111/jch.14141
20. Laine C and Wee CC. Overweight and obesity: Current clinical challenges. Ann Intern Med. 2023;176(5):699-700.
https://doi.org/10.7326/M23-0628
21. Zoler ML. BMI is a Flawed Measure of Obesity. What are Alternatives? Medscape; 2023. Available from: https://www.medscape.com/viewarticle/991210 [Last accessed on 2024 Apr 12].
22. Kontis V, Mathers CD and Rehm J. Tackling the non-communicable disease epidemic: A framework for global action. Lancet Global Health. 2024;45(2):105-109.
23. Boer P. Estimated lean body mass as an index for normalization of body fluid volumes in humans. Am J Physiol Endocrinol Metab. 1984;247(4 Pt 2):F632-F636.
https://doi.org/10.1152/ajprenal.1984.247.4.F632
24. Jensen MD, Ryan DH, Apovian CM, Ard JD, Comuzzie AG, Donato KA, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. J Am Coll Cardiol. 2014;63(25 Part B):2985-3023.
25. Caruso D, De Santis D, Rivosecchi F, Bellini D, Carbone M, Laghi A, et al. Lean body weight-tailored iodinated contrast injection in obese patient: Boer versus James formula. Biomed Res Int. 2018;2018:8521893.
26. National Institute for Health and Care Excellence (NICE). Obesity: Identification, Assessment, and Management. NICE Guideline No. 189; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK588750 [Last accessed on 2024 Apr 12].
27. Karastergiou K, Smith SR, Greenberg AS and Fried SK. Sex differences in human adipose tissues - the biology of pear shape. Biol Sex Differ. 2012;3(1):13.
https://doi.org/10.1186/2042-6410-3-13
28. Costantino S, Paneni F and Cosentino F. Ageing, metabolism, and cardiovascular disease. J Physiol. 2016;594(8):2061-2073.
https://doi.org/10.1113/JP270538
29. Wen X, Zhang B, Wu B, Xiao H, Li Z, Li R, *et al.* Signaling pathways in obesity: mechanisms and therapeutic interventions. Signal Transduct Target Ther. 2022;7(1):298.
https://doi.org/10.1038/s41392-022-01149-x
30. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004;363(9403):157-163.
https://doi.org/10.1016/S0140-6736(03)15268-3

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