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Original Research Article

Association between maternal vitamin D deficiency and pregnancy outcomes: a prospective study

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ABSTRACT

Background: Cardiovascular risk is strongly influenced by excess adiposity, particularly abdominal fat accumulation. Body mass index (BMI) is routinely used to classify general adiposity but does not describe fat distribution. Waist-to-height ratio (WHtR) incorporates waist circumference relative to stature and may therefore better reflect central adiposity and associated metabolic risk. The aim is to compare WHtR and BMI for identifying increased cardiovascular risk among urban adults in Hyderabad, Telangana.

Methods: A cross-sectional observational study was conducted among 70 adults aged 18–60 years. Weight, height, waist circumference and blood pressure were measured using standard procedures. Fasting plasma glucose and lipid profile were assessed. BMI and WHtR were calculated, and increased cardiovascular risk was defined as the presence of at least two non-anthropometric cardiometabolic abnormalities: elevated blood pressure, elevated fasting glucose, hypertriglyceridaemia and/or reduced HDL-C. Associations were examined using group comparisons and Pearson correlation. Receiver operating characteristic (ROC) analysis was used to compare the discriminatory performance of BMI and WHtR.

Results: The mean age was 41.6 ± 10.8 years. BMI ≥ 25 kg/m² was present in 39 (55.7%) participants, whereas WHtR ≥ 0.50 was present in 45 (64.3%). Participants with WHtR ≥ 0.50 had significantly higher frequencies of elevated blood pressure, elevated fasting glucose, hypertriglyceridaemia, reduced HDL-C and clustering of at least two cardiometabolic abnormalities. WHtR correlated more strongly than BMI with the measured cardiometabolic variables. ROC analysis showed an AUC of 0.82 (95% CI: 0.72–0.92) for WHtR and 0.71 (95% CI: 0.59–0.83) for BMI.

Conclusions: In this study population, WHtR showed better discrimination than BMI for the defined cardiometabolic risk outcome. WHtR may be a useful adjunct to BMI in simple cardiovascular risk screening among urban Indian adults.

Keywords: Body mass index, Cardiovascular risk, Central obesity, Obesity, Waist-to-height ratio, Urban adults

INTRODUCTION

Cardiovascular diseases (CVDs) remain a major cause of morbidity and mortality, and their development is closely

linked to modifiable risk factors such as obesity, hypertension, abnormal glucose metabolism and dyslipidaemia. Excess adiposity contributes to cardiovascular risk through insulin resistance, chronic

low-grade inflammation, endothelial dysfunction and adverse changes in lipid metabolism.^{1,2} Identification of individuals with an unfavourable metabolic profile is therefore an important component of cardiovascular prevention.

Body mass index (BMI), calculated from weight and height, is widely used to classify underweight, normal weight, overweight and obesity.³ Its clinical utility lies in its simplicity and reproducibility. However, BMI is an index of body size rather than fat distribution and does not distinguish visceral adiposity from peripheral fat or lean mass.⁴ Consequently, individuals with similar BMI values may have substantially different metabolic risk profiles.

This limitation is particularly relevant in South Asian populations. At comparable BMI levels, South Asians may have greater abdominal and visceral adiposity and may develop diabetes and other cardiometabolic abnormalities at lower levels of overall body mass.^{5,6} Reliance on BMI alone may therefore fail to identify some individuals with clinically important central adiposity.

Waist-based measurements provide additional information about abdominal fat distribution. Waist circumference is useful but is influenced by body size and may require sex- or population-specific interpretation. Waist-to-height ratio (WHtR), calculated as waist circumference divided by height in the same units, adjusts waist circumference for stature and provides a dimensionless measure of central adiposity.⁷ A value around 0.50 has been proposed as a practical screening threshold in adults.

Systematic reviews and meta-analyses have reported that WHtR performs at least as well as, and in several analyses better than, BMI for detecting cardiometabolic abnormalities including hypertension, diabetes, dyslipidaemia and metabolic syndrome.^{8,9} Indian and South Asian studies have similarly shown that indices of central adiposity can be useful for cardiometabolic risk classification.^{5,10,11}

Urban populations in India are increasingly exposed to sedentary behaviour, dietary transition and excess adiposity. In this setting, a simple anthropometric measure that can be obtained without specialised equipment may be useful for initial risk stratification in outpatient and community practice. The present study was conducted to compare WHtR and BMI as anthropometric predictors of a predefined cardiometabolic risk outcome among urban adults in Hyderabad, Telangana.

METHODS

Study design and setting

This cross-sectional observational study was conducted from November 2025 to April 2026 at Shadan Institute of Medical Sciences, Hyderabad, Telangana. The study evaluated the relationship of BMI and WHtR with

measured cardiometabolic abnormalities in urban adult participants.

Study population

70 adults aged 18–60 years who resided in urban Hyderabad were included after written informed consent.

Inclusion criteria

Adults aged 18–60 years who were residents of urban Hyderabad, were willing to participate, and agreed to anthropometric, clinical and biochemical assessments were eligible.

Exclusion criteria

Pregnant women; individuals with marked abdominal distension or oedema; patients with severe acute illness; individuals with physical deformities that interfered with reliable anthropometric measurement; and participants for whom the required clinical or laboratory information was unavailable were excluded.

Data collection

Information was recorded using a structured study proforma. The recorded variables included demographic characteristics, relevant medical history, smoking status, history of diabetes mellitus and hypertension, medication use and other cardiovascular risk factors.

Anthropometric measurements

Body weight was measured with a calibrated weighing scale while participants wore light clothing and no footwear. Height was measured without footwear using a stadiometer, with the participant standing upright and the head positioned in the horizontal plane. BMI was calculated as weight in kilograms divided by height in metres squared (kg/m^2). For the primary comparison, BMI $\geq 25 \text{ kg}/\text{m}^2$ was used to identify overweight/obesity.³

Waist circumference was measured with a non-stretchable tape while the participant stood erect and relaxed. The measurement was obtained at the end of normal expiration using a standard anatomical landmark and recorded to the nearest 0.1 cm. WHtR was calculated by dividing waist circumference in centimetres by height in centimetres. WHtR ≥ 0.50 was used as the screening threshold for increased central adiposity.⁷⁻⁹

Blood pressure measurement

Blood pressure was recorded after a period of seated rest using an appropriately sized cuff. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were documented. For the cardiometabolic risk definition used in this study, elevated blood pressure was defined as SBP

≥ 130 mmHg and/or DBP ≥ 85 mmHg, or current treatment for previously diagnosed hypertension.^{1,10}

Biochemical investigations

Following an overnight fast, venous blood was collected for estimation of fasting plasma glucose, total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C). Fasting plasma glucose ≥ 100 mg/dL, triglycerides ≥ 150 mg/dL and reduced HDL-C (<40 mg/dL in men and <50 mg/dL in women) were considered cardiometabolic abnormalities for the study analysis.^{2,10}

Definition of increased cardiovascular risk for the study analysis

Comparison of the two anthropometric indices without including either BMI or WHtR in the outcome definition, increased cardiovascular risk was operationally defined as the presence of two or more of the following non-anthropometric cardiometabolic abnormalities: elevated blood pressure, elevated fasting plasma glucose, hypertriglyceridaemia and reduced HDL-C. This composite outcome was used specifically as the study's cardiometabolic risk endpoint for comparative statistical analysis.

Group allocation

Maternal vitamin D status was determined by measurement of serum total 25-hydroxyvitamin D [25(OH)D].

For the principal analysis, participants were classified according to serum 25(OH)D concentration as; Group I – Vitamin D deficient/insufficient: 25(OH)D <50 nmol/L; Group II – Vitamin D sufficient: 25(OH)D ≥ 50 nmol/L;

Out of the 113 participants, 36 women (31.9%) were classified into Group I and 77 women (68.1%) into Group II. The 50 nmol/L threshold was selected to facilitate comparison with the principal binary classification employed in the reference prospective cohort study.¹⁷

Statistical analysis

Continuous variables were summarised as Mean $\pm$ standard deviation, and categorical variables as frequency and percentage. Between-group comparisons were performed using the independent-samples t-test for continuous variables and the Chi-square test or Fisher's exact test for categorical variables, as appropriate. Pearson correlation coefficients were calculated to examine the relationships of BMI and WHtR with selected cardiometabolic variables. ROC curves were constructed to evaluate the ability of BMI and WHtR to discriminate participants meeting the predefined increased-risk outcome. AUC, sensitivity, and specificity were reported. A $p < 0.05$ was considered statistically significant.

RESULTS

All 70 enrolled participants were included in the analysis. Their mean age was 41.6 ± 10.8 years; 38 (54.3%) were male and 32 (45.7%) were female. The mean BMI was 25.7 ± 4.1 kg/m² and the mean WHtR was 0.53 ± 0.07 . Mean SBP and DBP were 128.6 ± 15.4 mmHg and 82.1 ± 9.6 mmHg, respectively.

Table 1: Baseline characteristics of the study participants (n=70).

Parameter	Value
Age (years), mean $\pm$ SD	41.6 $\pm$ 10.8
Male	38 (54.3%)
Female	32 (45.7%)
Weight (kg), mean $\pm$ SD	69.8 $\pm$ 11.6
Height (cm), mean $\pm$ SD	164.8 $\pm$ 8.7
Waist circumference (cm), mean $\pm$ SD	86.9 $\pm$ 10.7
BMI (kg/m ²), mean $\pm$ SD	25.7 $\pm$ 4.1
WHtR, mean $\pm$ SD	0.53 $\pm$ 0.07
SBP (mmHg), mean $\pm$ SD	128.6 $\pm$ 15.4
DBP (mmHg), mean $\pm$ SD	82.1 $\pm$ 9.6
Fasting plasma glucose (mg/dL)	105.8 $\pm$ 24.7
Triglycerides (mg/dL)	151.7 $\pm$ 54.3
HDL-C (mg/dL)	43.9 $\pm$ 10.1

According to BMI categories, 3 (4.3%) participants were underweight, 28 (40.0%) had BMI 18.5–24.9 kg/m², 25 (35.7%) had BMI 25.0–29.9 kg/m² and 14 (20.0%) had BMI ≥ 30 kg/m². Overall, 39 (55.7%) had BMI ≥ 25 kg/m². In comparison, 45 (64.3%) participants had WHtR ≥ 0.50 .

Table 2: Distribution according to BMI and WHtR categories.

Anthropometric category	Number	Percentage
BMI <18.5 kg/m ²	3	4.3
BMI 18.5–24.9 kg/m ²	28	40.0
BMI 25.0–29.9 kg/m ²	25	35.7
BMI ≥ 30 kg/m ²	14	20.0
BMI ≥ 25 kg/m ²	39	55.7
WHtR <0.50	25	35.7
WHtR ≥ 0.50	45	64.3

Cardiometabolic abnormalities were more frequent among participants with WHtR ≥ 0.50 . Elevated blood pressure was present in 44.4% versus 20.0% ($P=0.041$), fasting glucose ≥ 100 mg/dl in 55.6% versus 28.0% ($P=0.027$), triglycerides ≥ 150 mg/dl in 51.1% versus 24.0% ($P=0.029$), and reduced HDL-C in 57.8% versus 32.0% ($P=0.039$). The predefined composite outcome of at least two cardiometabolic abnormalities was present in 55.6%

of participants with WHtR ≥ 0.50 compared with 20.0% of those with WHtR < 0.50 ($P=0.004$).

Table 3: Cardiovascular risk factors according to WHtR status.

Risk factor	WHtR <0.50 (n=25)	WHtR ≥ 0.50 (n=45)	P value
Elevated blood pressure	5 (20.0%)	20 (44.4%)	0.041
Fasting glucose ≥ 100 mg/dl	7 (28.0%)	25 (55.6%)	0.027
Triglycerides ≥ 150 mg/dl	6 (24.0%)	23 (51.1%)	0.029
Reduced HDL-C ≥ 2	8 (32.0%)	26 (57.8%)	0.039
cardiometabolic risk factors	5 (20.0%)	25 (55.6%)	0.004

When participants were grouped by BMI, elevated blood pressure and elevated fasting glucose were significantly more frequent in the BMI ≥ 25 kg/m² group. The between-group differences for hypertriglyceridaemia and reduced HDL-C did not reach statistical significance. The composite outcome of at least two cardiometabolic abnormalities occurred in 53.8% of participants with BMI ≥ 25 kg/m² and 29.0% of those with BMI < 25 kg/m² ($P=0.037$).

Table 4: Cardiovascular risk according to BMI status.

Parameter	BMI < 25 kg/m ² (n=31)	BMI ≥ 25 kg/m ² (n=39)	P value
Elevated blood pressure	7 (22.6%)	18 (46.2%)	0.040
Fasting glucose ≥ 100 mg/dl	10 (32.3%)	22 (56.4%)	0.044
Triglycerides ≥ 150 mg/dl	9 (29.0%)	20 (51.3%)	0.061
Reduced HDL-C ≥ 2	12 (38.7%)	22 (56.4%)	0.141
cardiometabolic risk factors	9 (29.0%)	21 (53.8%)	0.037

Both indices were correlated with the measured cardiometabolic variables, but the absolute correlation coefficients were consistently larger for WHtR. WHtR showed positive correlations with SBP ($r=0.46$), DBP ($r=0.40$), fasting plasma glucose ($r=0.48$) and triglycerides ($r=0.51$), and an inverse correlation with HDL-C ($r=-0.42$).

ROC analysis demonstrated an AUC of 0.82 (95% CI: 0.72–0.92) for WHtR and 0.71 (95% CI: 0.59–0.83) for BMI. At the reported optimal cut-off of 0.51, WHtR had a sensitivity of 83.3% and specificity of 72.5%. The corresponding BMI cut-off of 24.8 kg/m² had a sensitivity

of 70.0% and specificity of 62.5%. Within this sample, WHtR therefore showed greater discrimination for the predefined composite cardiometabolic risk outcome.

Table 5: Correlation of BMI and WHtR with selected cardiometabolic variables.

Variable	BMI, r	WHtR, r
Systolic blood pressure	0.34	0.46
Diastolic blood pressure	0.29	0.40
Fasting plasma glucose	0.31	0.48
Triglycerides	0.36	0.51
HDL-C	-0.28	-0.42

Table 6: ROC analysis of BMI and WHtR for predicting increased cardiovascular risk.

Parameter	AU C	95% CI	Cut- off	Sensiti vity	Specifi city
BMI	0.71	0.59– 0.83	24.8 kg/m ²	70.0%	62.5%
WHtR	0.82	0.72– 0.92	0.51	83.3%	72.5%

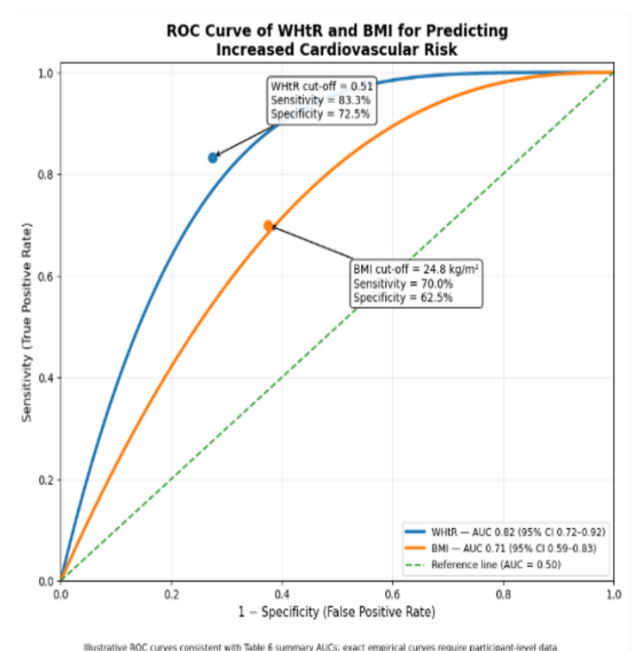


Figure 1: ROC curve of WHtR and BMI for predicting increased cardiovascular risk.

DISCUSSION

The present study compared WHtR and BMI in relation to a predefined cardiometabolic risk outcome among 70 urban adults in Hyderabad. The main observation was that WHtR showed stronger associations with the measured metabolic abnormalities and a higher ROC AUC than

BMI. These findings support the clinical relevance of central adiposity when simple anthropometric indices are used for cardiovascular risk screening.

The mean BMI of the study population was 25.7 ± 4.1 kg/m² and the mean WHtR was 0.53 ± 0.07 . More than half of the participants had BMI ≥ 25 kg/m², while nearly two-thirds had WHtR ≥ 0.50 . The higher proportion identified by the WHtR threshold should not be interpreted as direct evidence that WHtR diagnosed additional cases of cardiovascular disease; rather, it indicates that the two anthropometric criteria classified adiposity differently in this sample. This distinction is important because BMI reflects overall body mass relative to height, whereas WHtR specifically incorporates abdominal size.

The biological rationale for using central adiposity as a risk marker is well established. Visceral fat is metabolically active and is associated with insulin resistance, dyslipidaemia, inflammatory signalling and elevated blood pressure.^{1,2} BMI does not directly quantify visceral fat and may therefore provide incomplete information about the metabolic consequences of adiposity.^{3,4} This limitation is particularly relevant in South Asian populations, in whom cardiometabolic abnormalities may occur at lower BMI values and at comparatively greater levels of abdominal adiposity.^{5,6}

In the present analysis, participants with WHtR ≥ 0.50 had significantly higher frequencies of each of the four non-anthropometric cardiometabolic abnormalities assessed. The difference was most pronounced for the composite endpoint: 55.6% of participants with WHtR ≥ 0.50 had at least two abnormalities compared with 20.0% of those with WHtR < 0.50 . This pattern indicates that higher WHtR was associated with clustering of risk factors rather than with a single isolated abnormality.

Previous evidence is consistent with this observation. Browning et al reviewed WHtR as a screening measure for cardiovascular disease and diabetes and proposed approximately 0.50 as a practical boundary value.⁷ Ashwell et al subsequently reported that WHtR had favourable discriminatory performance compared with BMI and waist circumference for several adult cardiometabolic outcomes.⁸ Savva et al also found WHtR to be a useful predictor of cardiometabolic risk in meta-analytic comparisons.⁹

Indian data provide additional context. Rajput et al evaluated several anthropometric indices for prediction of metabolic syndrome and reported useful discriminatory performance for WHtR, with an optimal value close to 0.52.¹⁰ The optimal WHtR cut-off of 0.51 in the present analysis is numerically similar. However, direct equivalence should be interpreted cautiously because the study populations and outcome definitions are not identical.

The CARRS study also demonstrated the value of central-obesity measures for cardiovascular risk classification among South Asian adults.¹¹ Although no single anthropometric index is necessarily superior for every cardiometabolic outcome, these findings reinforce the importance of assessing abdominal adiposity in addition to general body size. Earlier studies by Hsieh and Yoshinaga and Ashwell and Gibson similarly described WHtR as a simple anthropometric marker associated with coronary and metabolic risk factors.^{12,13} The potential advantage of dividing waist circumference by height is that the resulting index accounts, at least partly, for differences in stature. This may improve interpretation compared with an absolute waist measurement alone.^{7,14}

The BMI-based comparison in the present study also showed meaningful associations. Participants with BMI ≥ 25 kg/m² had higher frequencies of elevated blood pressure, elevated fasting glucose and the composite risk outcome. However, differences in triglycerides and HDL-C did not reach statistical significance. Thus, the present results do not indicate that BMI lacks clinical value; rather, they suggest that WHtR provided a stronger relationship with the selected metabolic abnormalities in this particular sample.

The correlation analysis showed the same overall pattern. Compared with BMI, WHtR had stronger correlations with SBP, DBP, fasting plasma glucose and triglycerides and a stronger inverse correlation with HDL-C. The largest coefficient observed was between WHtR and triglycerides ($r=0.51$). These are moderate associations and should not be interpreted as evidence of causation, but their consistency across the measured variables supports the relationship between abdominal adiposity and an adverse metabolic profile.

The ROC findings further differentiated the two indices. WHtR had an AUC of 0.82 compared with 0.71 for BMI. At the reported optimal thresholds, WHtR also had higher sensitivity and specificity. These values indicate better discrimination of the study-defined composite outcome by WHtR within the analysed sample. They do not establish WHtR as a stand-alone predictor of future myocardial infarction, stroke or cardiovascular mortality because the study was cross-sectional and did not measure prospective cardiovascular events.

From a practical perspective, WHtR is inexpensive and requires only waist and height measurements. A threshold near 0.50 is also straightforward to communicate. Nevertheless, WHtR should be regarded as a screening measure rather than a replacement for comprehensive cardiovascular assessment. Age, smoking, blood pressure, glycaemic status, lipid levels, family history and other established risk determinants remain essential components of clinical evaluation.

Overall, the present findings suggest that adding WHtR to routine anthropometric assessment may improve

recognition of adults with clustered cardiometabolic abnormalities in an urban South Indian setting. The results are consistent with previous South Asian and international literature, while remaining specific to the operational risk definition and sample examined in this study.^{8-11,15}

Limitations

The study included a relatively small sample of 70 participants from a single centre, which limits precision and generalisability. The cross-sectional design permits assessment of associations but cannot establish temporal or causal relationships. The outcome termed increased cardiovascular risk was an operational composite of cardiometabolic abnormalities and did not represent a validated prospective cardiovascular risk score or actual cardiovascular events. Potential confounders such as dietary intake, physical activity, socioeconomic status and family history were not comprehensively evaluated.

CONCLUSION

Among the urban adults included in this cross-sectional study, WHtR was more strongly associated than BMI with the measured cardiometabolic abnormalities and showed better discrimination for the predefined composite risk outcome. A WHtR close to 0.50 may therefore be useful as a simple screening indicator of central adiposity and clustered cardiometabolic risk. BMI remains useful for assessment of general adiposity, and the two measures may be complementary rather than mutually exclusive. Because the study was small and cross-sectional, the findings should be interpreted as evidence of association and screening performance within this sample, not as proof of prediction of future cardiovascular events.

Future scope

Larger multicentre studies involving diverse populations from Telangana and other regions of India are needed to confirm the observed associations. Prospective studies should evaluate whether WHtR predicts incident cardiovascular events and whether it adds value to established cardiovascular risk models.

Future analyses should assess age- and sex-specific performance and determine whether a single WHtR threshold remains appropriate across population subgroups. Studies incorporating detailed lifestyle, socioeconomic and family-history variables may clarify the independent contribution of WHtR after adjustment for potential confounders.

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