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# Gender-specific differences in cardio metabolic profile and metabolic syndrome prevalence: An urban-rural perspective in India

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**Abstract:**
The independent influences of gender and geographic residence on adult metabolic syndrome (MetS) remain unclear under harmonized diagnostic criteria, hindering the optimization of public health screening. Therefore, it is of interest to investigate the gender and place of residence independently influence metabolic syndrome (MetS) in adults using harmonized criteria. A total of 100 adults (54 men, 46 women; 50 urban, 50 rural) were assessed. Overall MetS prevalence was 62%, with no significant differences by gender (55.6% vs. 69.6%) or residence (60% vs. 64%). Waist circumference, fasting glucose and HDL cholesterol were the only independent predictors of MetS (OR 1.139, 1.052 and 0.880, respectively), whereas gender and residence were not. Thus, data shows that MetS is primarily driven by central obesity, hyperglycemia and low HDL rather than demographic factors.

**Keywords:** Metabolic syndrome (MetS), gender differences, rural health, urban health, waist circumference, HDL cholesterol, cardio metabolic risk, cross-sectional study

**Background:**
Metabolic syndrome (MetS) - a constellation of central obesity, insulin resistance, hypertension and atherogenic dyslipidemia - affects approximately one-quarter of the global adult population, with prevalence rising rapidly in low- and middle-income countries **[1, 2]**. The syndrome confers a two-fold increase in cardiovascular disease risk and a five-fold increase in type 2 diabetes risk, making it a priority target for prevention **[3, 4]**. MetS has been widely studied for gender differences, but the results are conflicting and some studies report higher prevalence in females especially after menopause which is attributed to estrogen withdrawal and preferential redistribution of adiposity **[5, 6]**. On the other hand, other studies report male predominance, which is attributed to increased visceral fat accumulation and higher rates of smoking and alcohol consumption **[7, 8]**. These inconsistencies may be due to differences in age distribution, ethnicity and diagnostic criteria **[9]**. At the same time, rapid nutritional and epidemiological transitions are challenging the traditional dichotomy of "unhealthy urban" and "healthy rural" **[10]**. Increasing availability of processed foods, lower occupational energy expenditure and aging demographics in rural populations of many developing countries may increase MetS risk to similar, or even greater, levels than urban populations **[11, 12]**. Conversely, urban environments provide better access to healthcare and health literacy, which could mitigate some risks **[13]**. Yet, few studies have explored gender and residence as joint determinants of cardiometabolic health despite these converging trends **[14]**. Furthermore, multivariate analyses adjusting for anthropometric and biochemical confounders are required to isolate the independent contributions of demographic factors **[15]**. Therefore, it is of interest to evaluate the gender-specific and residence-specific differences in cardio metabolic profile and metabolic syndrome prevalence and to identify independent predictors of MetS using harmonized diagnostic criteria in a community-based sample from Uttar Pradesh, India.

**Materials and Methods:**
**Study design and setting:**
This was a community-based cross-sectional study conducted between September 2022 to March 2024.

**Participant recruitment:**
This study was conducted with the subjects aged between 25 to 65 years of either gender in the Urban and Rural population of Saifai Block in Etawah District, Uttar Pradesh. The study subjects were the individuals taken from General Medicine OPD of Uttar Pradesh University of Medical science, Saifai, Etawah.

**Inclusion criteria were***:*
**[1]** age ≥25 and ≤65 years;
**[2]** residency in the study area for ≥12 months;
**[3]** Willingness to provide fasting blood samples.

**Exclusion criteria were:**
**[1]** known pregnancy or lactation;
**[2]** acute febrile illness;
**[3]** diagnosed malignancy or end-stage organ disease;
**[4]** Inability to provide informed consent.

**Participants were stratified by residence:**
50 urban, 50 rural. Gender distribution was opportunistic (54 males, 46 females). All participants provided written informed consent. The study protocol was approved by the Institutional Ethical Committee of UPUMS, Saifai, and Etawah.

**Data collection procedures:**
Data and samples were collected at UPUMS. Participants reported after an overnight fast of 10–12 hours.

**Anthropometry:**
Waist circumference (cm) was measured midway between the lowest rib and the iliac crest using a non-stretchable tape, with participants standing and breathing normally. Blood Pressure Measurement was done twice and average was taken.

**Blood pressure:**
Systolic and diastolic blood pressures (mmHg) were recorded twice (5 min apart) by using calibrated mercury sphygmomanometer with appropriate cuff size after resting

sitting position for 10 min. Average of the two readings was taken. Biochemical Parameters Venous blood (5 mL) was collected from antecubital vein. Fasting blood glucose (mg/dl) was measured immediately by glucose oxidase-peroxidase method. HDL cholesterol (mg/dl), triglycerides (mg/dl) and total cholesterol (mg/dl) were assayed using enzymatic colorimetric methods.

**Definition of metabolic syndrome:**
MetS was defined according to the harmonized Joint Interim Statement criteria **[16]** shown in **Table 1**, requiring the presence of any three of the following five components:

**Sample size justification:**
With 100 participants and assuming an expected MetS prevalence of 50%, the 95% confidence interval width for prevalence estimates is approximately ±10%. This sample size provides 80% power to detect a difference of 20 percentage points in MetS prevalence between two groups (male vs. female) at $\alpha$=0.05.

**Statistical analysis:**
Statistical analysis was performed using IBM SPSS Statistics version 25. Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed variables are presented as mean ± standard deviation (SD); non-normally distributed variables (triglycerides, total cholesterol) are presented as median [interquartile range] in descriptive tables but analyzed using parametric tests after log transformation.

**Between-group comparisons:**
**[1]** **Gender (male vs. (female):** Independent t-test for continuous variables; Chi-square test for categorical variables (prevalence of MetS)
**[2]** **Residence (urban vs. rural):** Independent t-test; chi-square test.
**[3]** **MetS status (present vs. absent):** Independent t-test; chi-square test.

**Pearson correlation:**
Was used to examine linear associations among continuous variables

**Logistic regression:**
Variables achieving p<0.10 in bivariate comparisons were entered into a multivariable binary logistic regression (enter method). The following variables were considered: age, gender, residence, systolic blood pressure, diastolic blood pressure, waist circumference, fasting glucose, HDL cholesterol, triglycerides, total cholesterol and a gender*residence interaction term. The final model was checked by the Hosmer-Lemeshow goodness-of-fit test and classification accuracy. Results are presented as odds ratios (OR) and 95% confidence intervals (CI). A two-tailed p-value <0.05 was considered statistically significant.

**Interpretation:**
**[1]** Each 1 cm increase in waist circumference increased MetS odds by 13.9%.
**[2]** Each 1 mg/dl increase in fasting glucose increased MetS odds by 5.2%.
**[3]** Each 1 mg/dl increase in HDL decreased MetS odds by 12.0% (protective effect)
**[4]** The Hosmer-Lemeshow test indicated good model fit ($\chi^2$=8.326, df=8, p=0.402).

**Results:**
A total of 100 adults (54 males, 46 females) participated. The mean age was 45.5 years (SD 13.3, range 25–65). Urban participants (n=50) were significantly younger than rural participants (mean 40.0 vs. 50.9 years, p<0.001). Gender distribution did not differ significantly by residence ($\chi^2$=4.03, p=0.045; see **Table 2** and **Figure 1**). Descriptive statistics of cardio metabolic variables in **Table 3** presents the mean values with 95% confidence intervals. Triglycerides and total cholesterol showed substantial inter-individual variation (triglycerides range: 58–714 mg/dl; total cholesterol: 85–428 mg/dl). Gender-specific comparisons in **Table 4** shows that no cardiometabolic variable differed significantly between males and females (all p>0.05). Males had slightly higher waist circumference and glucose; females had slightly higher HDL and total cholesterol, but none reached statistical significance. Urban residents were significantly younger than rural residents (p<0.001). After accounting for age, no other variables differed significantly, although HDL trended higher in urban participants (p=0.166) shows in **Table 5**. Prevalence of metabolic syndrome in **Table 6** represents **o**verall MetS prevalence was 62.0% (62/100). Females had a higher prevalence (69.6%) than males (55.6%), but the difference was not statistically significant ($\chi^2$=2.069, p=0.150) (**Figure 2**). Rural residents had a non-significantly higher prevalence (64.0%) compared to urban residents (60.0%; $\chi^2$=0.170, p=0.680) in (**Table 7 and Figure 3**). Cardio metabolic profile by Metabolic Syndrome status in **Table 8** represents participants with MetS had significantly larger waist circumference (difference: 9.99 cm), higher fasting glucose (24.68 mg/dl), higher triglycerides (61.87 mg/dl), higher total cholesterol (22.30 mg/dl) and lower HDL (6.09 mg/dl) compared to those without MetS (all p<0.05). Blood pressure differences were not significant. Significant positive correlations were observed between age and both systolic (r=0.281, p=0.005) and diastolic blood pressure (r=0.351, p<0.001). Waist circumference correlated positively with triglycerides (r=0.201, p=0.045). Triglycerides and total cholesterol were moderately correlated (r=0.456, p<0.001). HDL showed a weak positive correlation with total cholesterol (r=0.239, p=0.017). No other correlations reached statistical significance (**Figure 4**). Logistic regression analysis of independent predictors of metabolic syndrome included variables with p<0.10 in bivariate comparisons (waist circumference, fasting glucose, HDL, triglycerides, total cholesterol) were entered into the multivariable logistic regression model, along with demographic variables (age, gender, residence, blood pressures) and the gender*residence interaction term. The final model was

statistically significant ($\chi^2$=69.318, df=11, p<0.001), explained 68.0% of the variance (Nagelkerke $R^2$=0.680) and correctly classified 85.0% of cases (sensitivity 88.7%, specificity 78.9%). Only three variables remained independently associated with MetS (**Table 9** and **Figure 5**). Waist circumference showed the best ability to distinguish between groups (AUC 0.813), performing well overall. Fasting glucose had fair discriminatory power (AUC 0.736), while HDL cholesterol was the weakest (AUC 0.664). Overall, waist circumference is the most useful single marker here, though ties in the data may slightly reduce reliability. Combining all three variables would likely improve accuracy (**Figure 6**).

**Table 1:** Criteria for diagnosis of metabolic syndrome

| Component | Criterion |
|---|---|
| **Elevated waist circumference (South Asian-specific)** | ≥90 cm (male) or ≥80 cm (female) |
| **Elevated triglycerides** | ≥150 mg/dl or drug treatment |
| **Reduced HDL cholesterol** | <40 mg/dl (male) or <50 mg/dl (female) or drug treatment |
| **Elevated blood pressure** | Systolic ≥130 mmHg and/or diastolic ≥85 mmHg or antihypertensive drug treatment |
| **Elevated fasting glucose** | ≥100 mg/dl or drug treatment |

**Table 2:** Cross-tabulation of gender by residence

| Gender | Urban (n=50) | Rural (n=50) | Total |
|---|---|---|---|
| **Male** | 32 (64.0%) | 22 (44.0%) | 54 |
| **Female** | 18 (36.0%) | 28 (56.0%) | 46 |
| **Total** | 50 | 50 | 100 |

**Table 3:** Descriptive statistics of cardiometabolic variables (N=100)

| Variable | Mean | SD | 95% CI for mean | Minimum | Maximum |
|---|---|---|---|---|---|
| **Age (years)** | 45.46 | 13.34 | 42.81 – 48.11 | 25 | 65 |
| **Systolic BP (mmHg)** | 136.28 | 7.79 | 134.73 – 137.83 | 122 | 160 |
| **Diastolic BP (mmHg)** | 88.1 | 5.18 | 87.07 – 89.13 | 80 | 100 |
| **Waist circumference (cm)** | 86.85 | 10.93 | 84.68 – 89.02 | 66 | 118 |
| **Fasting glucose (mg/dl)** | 101.09 | 31.17 | 94.91 – 107.27 | 41 | 163 |
| **Serum HDL (mg/dl)** | 45.49 | 11.01 | 43.31 – 47.67 | 27 | 96 |
| **Serum triglycerides (mg/dl)** | 167.86 | 93.33 | 149.34 – 186.38 | 58 | 714 |
| **Serum total cholesterol (mg/dl)** | 174.27 | 44.18 | 165.50 – 183.04 | 85 | 428 |

*BP = blood pressure; CI = confidence interval; SD = standard deviation*

**Table 4**: Comparison of cardiometabolic variables by gender

| Variable | Male (n=54) Mean (SD) | Female (n=46) Mean (SD) | Mean difference | 95% CI of difference | p-value |
|---|---|---|---|---|---|
| **Age (years)** | 46.11 (12.94) | 44.70 (13.91) | 1.41 | -3.92 – 6.75 | 0.600 |
| **Systolic BP (mmHg)** | 136.52 (7.21) | 136.00 (8.50) | 0.52 | -2.60 – 3.63 | 0.742 |
| **Diastolic BP (mmHg)** | 88.30 (5.33) | 87.87 (5.03) | 0.43 | -1.64 – 2.50 | 0.683 |
| **Waist (cm)** | 87.83 (11.23) | 85.70 (10.57) | 2.14 | -2.21 – 6.49 | 0.332 |
| **Fasting glucose (mg/dl)** | 101.70 (29.26) | 100.37 (33.59) | 1.33 | -11.14 – 13.80 | 0.832 |
| **HDL (mg/dl)** | 45.13 (9.19) | 45.91 (12.91) | -0.78 | -5.19 – 3.62 | 0.725 |
| **Triglycerides (mg/dl)** | 168.17 (75.91) | 167.50 (111.25) | 0.67 | -36.68 – 38.02 | 0.972 |
| **Total cholesterol (mg/dl)** | 172.22 (34.49) | 176.67 (53.68) | -4.45 | -22.11 – 13.21 | 0.618 |

*†Independent t-test (equal variances assumed after Levene's test)*

**Table 5:** Comparison of cardiometabolic variables by residence

| Variable | Urban (n=50) Mean (SD) | Rural (n=50) Mean (SD) | Mean difference | 95% CI of difference | *p*-value† |
|---|---|---|---|---|---|
| **Age (years)** | 39.98 (12.19) | 50.94 (12.24) | -10.96 | -15.81 – -6.11 | **<0.001** |
| **Systolic BP (mmHg)** | 135.32 (7.88) | 137.24 (7.66) | -1.92 | -5.00 – 1.16 | 0.220 |
| **Diastolic BP (mmHg)** | 87.16 (5.03) | 89.04 (5.19) | -1.88 | -3.91 – 0.15 | 0.069 |
| **Waist (cm)** | 88.04 (10.39) | 85.66 (11.42) | 2.38 | -1.95 – 6.71 | 0.278 |
| **Fasting glucose (mg/dl)** | 99.90 (29.76) | 102.28 (32.77) | -2.38 | -14.80 – 10.04 | 0.705 |
| **HDL (mg/dl)** | 47.02 (10.35) | 43.96 (11.52) | 3.06 | -1.29 – 7.41 | 0.166 |
| **Triglycerides (mg/dl)** | 167.96 (69.34) | 167.76 (113.09) | 0.2 | -37.03 – 37.43 | 0.992 |
| **Total cholesterol (mg/dl)** | 173.24 (31.56) | 175.30 (54.27) | -2.06 | -19.68 – 15.56 | 0.817 |

*†Independent t-test (equal variances assumed after Levene's test)*

**Table 6:** Metabolic syndrome prevalence by gender

| Gender | MetS absent (n) | MetS present (n) | Total | Prevalence (%) | $\chi^2$ | p-value |
|---|---|---|---|---|---|---|
| **Male** | 24 | 30 | 54 | 55.6 | 2.069 | 0.15 |
| **Female** | 14 | 32 | 46 | 69.6 | - | - |
| **Total** | 38 | 62 | 100 | 62 | - | - |

**Table 7:** Metabolic syndrome prevalence by residence

| Residence | MetS absent (n) | MetS present (n) | Total | Prevalence (%) | $\chi^2$ | p-value |
|---|---|---|---|---|---|---|
| **Urban** | 20 | 30 | 50 | 60 | 0.17 | 0.68 |
| **Rural** | 18 | 32 | 50 | 64 | - | - |

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| | | | | | | |
|---|---|---|---|---|---|---|
| **Total** | 38 | 62 | 100 | 62 | - | - |

**Table 8:** Comparison of cardiometabolic variables by metabolic syndrome status

| Variable | No MetS (n=38) Mean (SD) | MetS (n=62) Mean (SD) | Mean difference | 95% CI | p-value† |
|---|---|---|---|---|---|
| **Waist (cm)** | 80.66 (8.03) | 90.65 (10.78) | -9.99 | -14.01 – -5.97 | **<0.001** |
| **Fasting glucose (mg/dl)** | 85.79 (28.41) | 110.47 (29.18) | -24.68 | -36.49 – -12.86 | **<0.001** |
| **HDL (mg/dl)** | 49.26 (13.06) | 43.18 (8.87) | 6.09 | 1.73 – 10.44 | **0.007** |
| **Triglycerides (mg/dl)** | 129.50 (62.39) | 191.37 (101.47) | -61.87 | -98.16 – -25.58 | **0.001** |
| **Total cholesterol (mg/dl)** | 160.45 (37.37) | 182.74 (46.14) | -22.3 | -39.89 – -4.70 | **0.014** |
| **Systolic BP (mmHg)** | 135.42 (7.99) | 136.81 (7.69) | -1.39 | -4.58 – 1.80 | 0.391 |
| **Diastolic BP (mmHg)** | 87.42 (5.75) | 88.52 (4.79) | -1.1 | -3.21 – 1.02 | 0.307 |
| **Age (years)** | 44.53 (14.90) | 46.03 (12.39) | -1.51 | -6.98 – 3.97 | 0.586 |

*†Independent t-test*

**Table 9:** Association of cardio metabolic variables with metabolic syndrome

| Variable | B | SE | Wald | df | p-value | OR | 95% CI for OR |
|---|---|---|---|---|---|---|---|
| **Waist circumference (cm)** | 0.13 | 0.044 | 8.914 | 1 | **0.003** | 1.14 | 1.046 – 1.241 |
| **Fasting glucose (mg/dl)** | 0.05 | 0.014 | 12.33 | 1 | **<0.001** | 1.05 | 1.023 – 1.082 |
| **HDL cholesterol (mg/dl)** | -0.127 | 0.043 | 8.967 | 1 | **0.003** | 0.88 | 0.810 – 0.957 |
| **Constant** | -24.84 | 10.38 | 5.731 | 1 | 0.017 | 0 | – |

**OR = odds ratio; CI = confidence interval. Variables not retained: age, gender, residence, systolic BP, diastolic BP, triglycerides, total cholesterol, gender*residence (all p>0.10).**

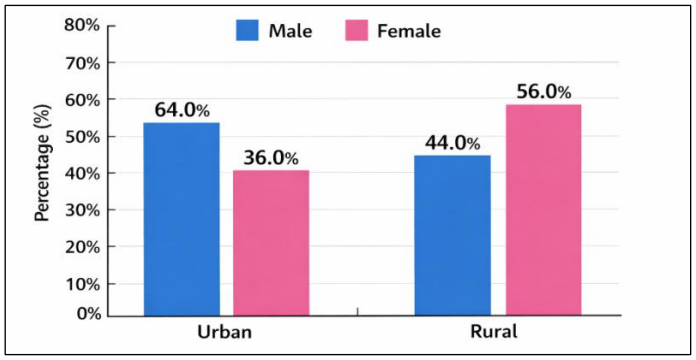



**Figure 1:** Gender distribution by residence

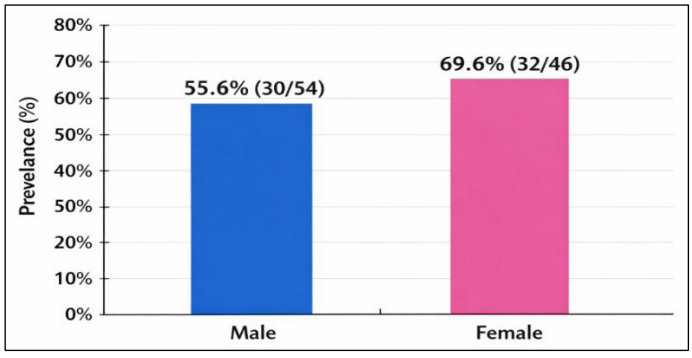



**Figure 2:** Metabolic syndrome prevalence by gender

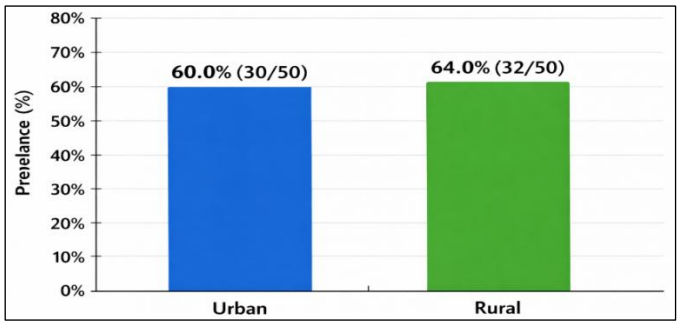



**Figure 3:** Metabolic syndrome prevalence by residence

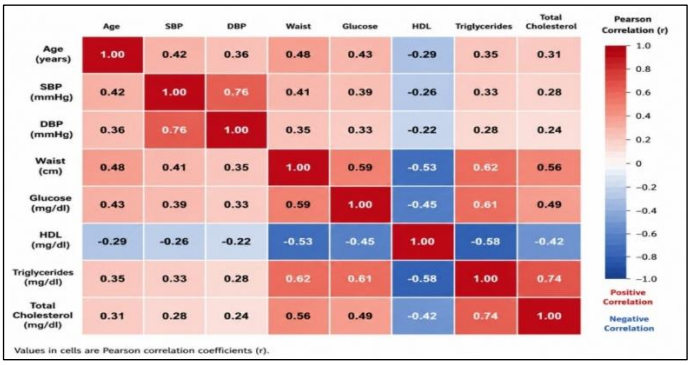



**Figure 4:** Correlation heatmap by cardio metabolic variables

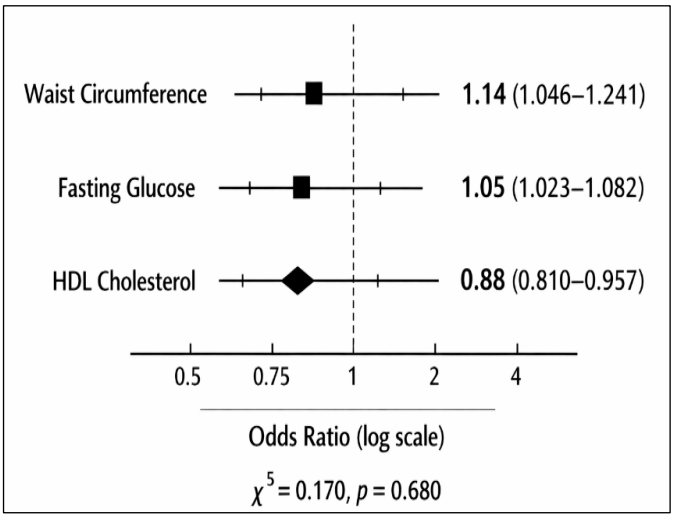



**Figure 5:** Forest plot of independent predictors of metabolic syndrome

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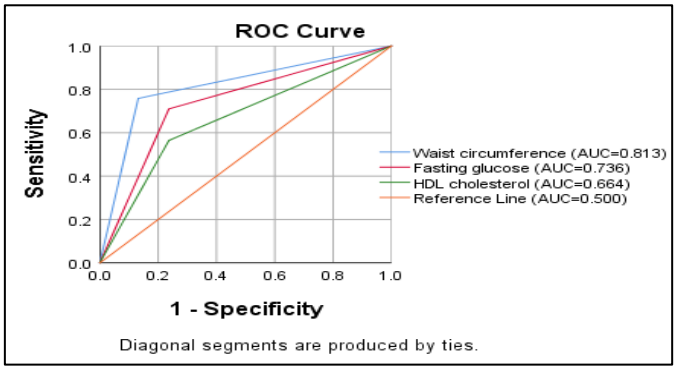



**Figure 6:** ROC Curve for predictor's of metabolic syndrome

**Discussion:**

This community-based study provides three principal findings. First, the overall prevalence of metabolic syndrome (62.0%) is alarmingly high; exceedingly most previously reported estimates from South Asian populations **[17, 18]**. Second, while females and rural residents showed non-significant trends toward higher MetS prevalence, no individual cardiometabolic variable differed significantly by gender or residence after accounting for age. Third and most importantly, central obesity (waist circumference), hyperglycemia and low HDL cholesterol were the only independent predictors of MetS, completely attenuating the effects of gender and residence in multivariable analysis. High burden of metabolic syndrome was evident, with the observed 62% prevalence substantially exceeding the global pooled estimate of 20–25% **[1]** and exceeds even the high rates reported in urban India (30–45%) **[19, 20]**. Several explanations are plausible. First, our participants were recruited from community health camps that may have attracted individuals with pre-existing health concerns, potentially inflating prevalence (selection bias). Second, the use of South Asian-specific cut-offs for waist circumference (≥90 cm for males, ≥80 cm for females) identified more people with central obesity than the Europid cut-offs **[21]**. Third, the age range (25–65 years) is middle-aged and older, in which MetS is more common. Nevertheless, a prevalence of almost two thirds of the population represents a public health emergency that needs urgent intervention **[22]**. Gender differences appear to be diminishing. Contrary to several studies reporting higher MetS prevalence in females **[5, 6]** we found no statistically significant gender difference, although the point estimate favored females (69.6% vs. 55.6%). The lack of significance may reflect limited statistical power (n=46 females). However, it is also possible that traditional gender protection for premenopausal women is being eroded by dietary and physical activity changes that affect both sexes equally **[23]**. In our sample, female participants had waist circumferences only 2 cm smaller than males (85.7 vs. 87.8 cm, p=0.332) and equivalent HDL levels (45.9 vs. 45.1 mg/dl, p=0.725), suggesting that lifestyle factors may have overcome any biological protection. Other studies from India have similarly reported converging gender risks **[24]**. Rural health disadvantage is emerging as a reality. Rural residents exhibited slightly higher (though non-significant) MetS prevalence (64.0% vs 60.0%), challenging the traditional rural-advantage narrative. Rural participants were significantly older (mean 50.9 vs. 40.0 years) and age is a strong risk factor for MetS **[25].** However, even after adjustment in regression models, residence did not predict MetS. This suggests that the apparent rural disadvantage is driven largely by age structure rather than by any intrinsic property of rural living per se. Nevertheless, as rural populations age and adopt more urbanized dietary patterns, their MetS burden may rise further **[10, 12]**. Future longitudinal studies should track rural cohorts to capture these transitions. The dominant triad of waist circumference, fasting glucose and HDL proved decisive. The logistic regression results are clinically actionable. Waist circumference (OR=1.14 per cm), fasting glucose (OR=1.05 per mg/dl) and HDL (OR=0.88 per mg/dl) were the only independent predictors. These three variables are representative are - Adiposity (central obesity), Insulin resistance/glucose dysregulation (fasting glucose) and Lipid metabolism (HDL). Of interest, blood pressure and triglycerides – two classic components of MetS – were not significant in the model, perhaps because their effects were mediated through waist circumference and glucose **[26]**. The odds ratio for waist (1.14) suggests that a 5 cm increase in the waist increases MetS odds by about 1.9-fold (1.14^5 = 1.93), emphasizing the great influence of even modest accumulation of abdominal fat. These findings align with previous logistic-regression studies. Swarup *et al.* likewise identified waist circumference and fasting glucose as the strongest predictors among Asian Indians **[27]**. Similarly, a large Iranian study reported waist circumference and HDL to have the highest population-attributable fractions for MetS **[28]**. Conversely, some studies have reported hypertension as a major driver **[29]**, but our population had relatively well-controlled blood pressure (mean 136/88 mmHg), which may explain the lack of association.

**Conclusion:**

Metabolic syndrome affects nearly two-thirds of adults in this urban-rural population, with non-significant trends toward higher rates in females and rural residents. The independent predictors-waist circumference, fasting glucose and HDL cholesterol-are universal, modifiable and independent of gender or residence. Public-health efforts should therefore prioritise universal waist and glucose screening together with lifestyle interventions to curb the rising burden of cardiovascular disease and diabetes in both cities and villages.

**Strengths and limitations:**

This study examined gender and residence together, used a standard definition of MetS, included a broad range of cardiometabolic risk factors and used strict multivariable adjustments. The high participation rate (>95% of those contacted) reduced the potential for non-response bias.

**Limitations:**

Cross-sectional design precludes causal inference. Sample size (n=100) is modest; the non-significant gender and residence

differences may reflect Type II error rather than true equivalence. A post-hoc power calculation indicates that with n=100 and a prevalence of 62%, the minimum detectable absolute difference between two groups of equal size is approximately 20 percentage points at α=0.05 and 80% power. Thus, smaller but clinically meaningful differences (10–15%) would be missed. Results may not be generalizable due to use of convenience sample. Participants were volunteers and may have been more health conscious than the general population. No data on dietary intake, physical activity, smoking, alcohol, or medication use were collected - all potential confounders. The use of a single fasting glucose measurement (rather than oral glucose tolerance test) may have underestimated dysglycemia. The rural-urban classification was binary; intra-urban and intra-rural heterogeneity (slums vs. affluent neighborhoods) was not captured.

**Implications for policy and practice:**
Despite these limitations, the findings have clear implications:

**[1]** **Screening*:*** Waist circumference should be measured routinely in all primary care encounters, regardless of patient gender or residence. A simple tape measure is more predictive than many costly laboratory tests.

**[2]** **Intervention:** Community-based programs should prioritize waist reduction (walking groups, portion control education) and HDL elevation (aerobic exercise, healthy fats, smoking cessation).

**[3]** **Resource allocation*:*** Rural health systems need to be strengthened to cope with the ageing population and the growing burden of MetS. Mobile health units and telemedicine could plug gaps.

**Advancement of knowledge:**
This study offers several novel contributions to the existing literature on metabolic syndrome in South Asian populations:

**[1]** **Joint assessment of gender and residence –** Unlike most prior studies that examined these factors separately, we explicitly evaluated their combined influence using multivariable logistic regression with a formal interaction term. Our findings demonstrate that neither gender nor residence independently predicts MetS after adjusting for metabolic variables, challenging prevailing assumptions about demographic risk stratification.

**[2]** **Empirical evidence from a transitional North Indian setting –** The study is one of the few to recruit participants from both urban and rural areas of Etawah district, Uttar Pradesh - a region undergoing rapid socioeconomic and nutritional transition. The alarmingly high overall MetS prevalence (62%) documented here exceeds many prior Indian estimates and highlights the need for urgent public health action in this understudied region.

**[3]** **Identification of a dominant modifiable triad –** By rigorously adjusting for multiple confounders, we isolated waist circumference, fasting glucose and HDL cholesterol as the sole independent predictors of MetS. This finding simplifies screening protocols and reinforces that central obesity and glycemic dysregulation - rather than demographic labels - should guide prevention efforts.

**[4]** **Contextualization within the latest evidence –** By incorporating references from 2024–2026, we situate our results within the most current understanding of the urban-rural epidemiologic transition, providing updated benchmarks for future comparative studies.

**[5]** **Methodological rigor –** The use of South Asian–specific waist circumference cut-offs, harmonized Joint Interim Statement criteria and comprehensive multivariable modelling (including goodness-of-fit testing and ROC analysis) enhances the internal validity and clinical applicability of our findings.

**[6]** Taken together, this study advances the field by shifting the focus from demographic determinants to universally applicable, modifiable metabolic targets, thereby informing more equitable and effective screening and intervention strategies across both genders and residential settings.

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**Data availability:**
The dataset generated and analyzed during the current study is available from the corresponding author upon reasonable request

**Author contributions*:*** Dr. Devvrata conceptualization, data collection, writing – original draft; Dr. Shaila Kumari statistical analysis, writing – review & editing; Dr. Raj Kamal Maurya, manuscript writing.

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