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RESEARCH ARTICLE

Low-Grade Albuminuria and Its Association with Metabolic Syndrome: Evidence from a Hospital-Based study

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Abstract: ***Introduction***: Low-grade albuminuria, defined as urinary albumin levels below the microalbuminuria threshold (<30 mg/L), has emerged as a potential early marker of metabolic and cardiovascular risk. While its association with metabolic syndrome (MetS) is established in Western populations, data in Indian cohorts remain limited. This study aimed to assess the relationship between low-grade albuminuria and MetS in Indian adults. ***Materials and methods*** This cross-sectional study included 300 individuals aged 35–65 years attending a tertiary-care hospital in Maharashtra, India. Participants were stratified into tertiles based on urine albumin levels: ≤5.6 mg/L, 5.6–8.0 mg/L, and >8.0 mg/L. Clinical, anthropometric, and biochemical parameters were analyzed. MetS was defined using NCEP ATP III criteria. Statistical analyses included ANOVA, chi-square, Kruskal-Wallis, and logistic regression. ***Results***: The prevalence of MetS increased across albuminuria tertiles: 40.0%, 32.1%, and 68.1%, respectively ($p < 0.001$). Individuals in the highest tertile had 3.31 times greater odds of MetS (95% CI: 1.84–5.95). Fasting glucose, DBP, HDL cholesterol, and waist-to-hip ratio significantly worsened with increasing albuminuria. ***Conclusion***: Low-grade albuminuria is strongly associated with metabolic syndrome and its components in this Indian population. Routine screening of urinary albumin, even at subclinical levels, may aid early identification of individuals at risk for cardiometabolic disease.

Keywords: Low-Grade Albuminuria, Microalbuminuria, Metabolic Syndrome (MetS), Cardiovascular Risk, Urinary Albumin-to-Creatinine Ratio (UACR).

INTRODUCTION

Subclinical elevations in urinary albumin excretion (UAE) were first identified in 1974 (1). This finding has drawn considerable scientific attention over the decades. Microalbuminuria (MA), a central feature of these elevations, is considered an early marker of renal and cardiovascular risk. Despite ongoing research, its underlying mechanisms and clinical relevance remain incompletely understood. Microalbuminuria, defined as a urinary albumin-to-creatinine ratio (UACR) of 30–300 mg/g, is a well-established clinical marker. It has long been recognized as a predictor of chronic kidney disease (CKD). Additionally, it plays a critical role in the early detection of diabetic nephropathy (2). It is also an established risk factor for cardiovascular disease (CVD) . More recently, several population-based studies have shown that even slight elevations of urinary albumin below the conventional micro-albuminuria threshold — termed low-grade albuminuria — are associated with increased risks of CVD, all-cause mortality, and metabolic disorders (3) (4) (5). Data from the HOPE and Framingham studies underscore that cardiovascular risk rises progressively with increasing UACR levels, even within ranges traditionally considered normal. (6) (7).

Metabolic syndrome (MetS) is a constellation of central obesity, elevated blood pressure, hyperglycaemia, hypertriglyceridaemia, and low high-density lipoprotein cholesterol (HDL-C) . It substantially increases the risk of type 2 diabetes and CVD (8). Micro-albuminuria has been linked with MetS and its individual components in diverse populations .More recent evidence suggests that low-grade albuminuria — even in individuals without diabetes or hypertension — is also related to MetS and other cardiometabolic risk factors (6) (9) (10)

However, information on the association between low-grade albuminuria and MetS in Indian subjects remains scarce. Identifying this relationship may help in early detection of vascular and metabolic risk among individuals considered to have “normal” urinary albumin excretion.

The present study aimed to investigate the association between low-grade albuminuria and the prevalence of MetS and its components in a cohort of subjects attending a tertiary-care hospital By examining urine albumin levels below the micro-albuminuria threshold (<30 mg/L), we sought to evaluate whether minor increments of albumin excretion are linked with MetS in this population.

MATERIALS AND METHODS

Study Design and Participants

This cross-sectional study was conducted in the Department of General Medicine, Dr. D. Y. Patil Medical College, Maharashtra, India. Data from 300 subjects aged 35–65 years were retrieved from the laboratory database. All participants had complete records of anthropometric indices, blood pressure, biochemical variables, and urine albumin. Subjects with hypothyroidism, pregnancy, malignancy, familial

dyslipidaemia, secondary hypertension, or ascites were excluded.

Ethics Statement

The study protocol was approved by the Institutional Ethics Committee of Dr. D. Y. Patil Medical College DMCK/88/2017. Written informed consent had been obtained from participants at the time of sample collection.

Clinical and Anthropometric Information

Age and sex were obtained from medical records. Blood pressure was measured in the sitting position using a mercury sphygmomanometer after a 5-minute rest. Waist and hip circumferences were measured to the nearest 0.1 cm, and the waist-to-hip ratio (WHR) was calculated**.**

Laboratory Measurements

Fasting venous blood was collected after an overnight fast. Fasting blood sugar, total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL) were measured using an automated analyser and standard enzymatic reagents. Serum creatinine, blood urea, and uric acid were assayed by routine methods. Urine albumin concentration was determined by a colorimetric method and expressed in mg/L.

Definition of Variables

Metabolic syndrome (MetS) was diagnosed according to the National Cholesterol Education Program–Adult Treatment Panel III (NCEP ATP III) criteria. Presence of ≥3 of the following was considered MetS: WHR >0.90 (men) or >0.85 (women); triglycerides ≥150 mg/dL; HDL <40 mg/dL (men) or <50 mg/dL (women); blood pressure ≥130/85 mmHg; fasting glucose ≥100 mg/dL. Urine albumin was stratified into tertiles: ≤5.6 mg/L, 5.6–8.0 mg/L, and >8.0 mg/L (low-grade albuminuria).

Statistical Analysis

Data were analysed using SPSS version 16. Continuous variables were summarised as mean ± standard deviation; categorical variables as frequencies and percentages. Comparisons between albuminuria groups were performed using the chi-square test for categorical variables and one-way analysis of variance (ANOVA) for continuous variables. A two-tailed p value <0.05 was considered statistically significant.

RESULT:

1. Prevalence of Metabolic Syndrome Across Albuminuria Tertiles

There was a significant association between albuminuria levels and the prevalence of MetS. The prevalence increased progressively across the tertiles: 40.0% in the lowest, 32.1% in the middle, and 68.1% in the highest tertile. This association was statistically significant ($\chi^2 = 28.18$, $p = 7.6 \times 10^{-7}$), indicating that low-grade albuminuria is strongly linked with MetS.

Table 1: Association Between Albuminuria Tertiles and Metabolic Syndrome

Albuminuria Group (mg/L)	No MetS (n)	MetS (n)	Total (n)	Prevalence of MetS (%)
Lowest tertile (≤5.6)	60	40	100	40.0
Middle tertile (5.6–8.0)	72	34	106	32.1
Upper tertile (>8.0)	30	64	94	68.1
Total	162	138	300	—

2. Baseline Characteristics Across Albuminuria Tertiles

The baseline clinical and biochemical characteristics of participants across albuminuria tertiles are shown in Table 4. The upper tertile had higher values of SBP, DBP, fasting glucose, and triglycerides, and lower HDL levels, indicating increased cardiometabolic risk.

Table 2: Baseline Characteristics Across Albuminuria Tertiles

Albuminuria Tertile	Lowest (≤5.6)	Middle (5.6–8.0)	Upper (>8.0)
N	102	104	94
SBP (mmHg)	144.9 ± 8.76	146.71 ± 8.05	147.23 ± 7.95
DBP (mmHg)	85.29 ± 5.02	85.0 ± 5.02	87.02 ± 4.6
Fasting Glucose (mg/dL)	101.16 ± 23.09	98.85 ± 16.04	140.81 ± 55.56
Triglycerides (mg/dL)	175.82 ± 63.83	184.37 ± 84.01	195.04 ± 66.1
HDL (mg/dL)	52.8 ± 4.92	53.37 ± 5.49	51.17 ± 5.82
WHR	2.37 ± 10.89	0.84 ± 0.05	0.86 ± 0.05
BMI	—	—	—

3. Comparision of Metabolic Parameters Across Albuminuria Tertiles

The Kruskal-Wallis test revealed statistically significant differences in several metabolic parameters across albuminuria tertiles. Fasting glucose levels differed most markedly (**H = 53.26**, $p < 0.001$), indicating a strong association between higher urine albumin and elevated blood glucose. Significant differences were also observed for **diastolic blood pressure** ($p = 0.009$), **HDL cholesterol** ($p = 0.016$), and **waist-to-hip ratio** ($p = 0.015$), with participants in the highest tertile

showing more adverse profiles. Triglyceride levels showed a borderline trend toward significance (p = 0.056), while systolic blood pressure was not significantly different across tertiles (p = 0.269). **BMI** was not included due to missing or inconsistent data.

Table 3: Kruskal-Wallis Test Results for Metabolic Variables Across Albuminuria Tertiles

Variable	H Statistic	p-value	Significance
Systolic BP (SBP)	2.62	0.269	—
Diastolic BP (DBP)	9.43	0.009	**
Fasting Glucose	53.26	<0.001	***
Triglycerides	5.76	0.056	~
HDL Cholesterol	8.26	0.016	*
Waist-to-Hip Ratio	8.45	0.015	*
BMI	—	—	Not tested

4. Gender Distribution Across Albuminuria Tertiles

There was a male predominance across all albuminuria tertiles, with the proportion increasing slightly in the upper tertile.

Table 4: Gender Distribution Across Albuminuria Tertiles

Albuminuria Tertile	Male n (%)	Female n (%)
Lowest (≤5.6)	60 (58.8%)	42 (41.2%)
Middle (5.6–8.0)	70 (67.3%)	34 (32.7%)
Upper (>8.0)	66 (70.2%)	28 (29.8%)

5. Logistic Regression Analysis: Odds of MetS by Albuminuria Tertiles

Logistic regression analysis showed a significant association between upper albuminuria tertiles and the presence of metabolic syndrome. Individuals in the **upper tertile (>8.0 mg/L)** had **3.31 times higher odds** of having MetS compared to those in the **lowest tertile (≤5.6 mg/L)** (95% CI: 1.84–5.95).

The **middle tertile (5.6–8.0 mg/L)** showed no statistically significant difference (OR: 0.75, 95% CI: 0.43–1.33).

Table 5: Logistic Regression for Metabolic Syndrome by Albuminuria Tertiles

Variable	OR	95% CI	p-value
Intercept	0.65	0.43 – 0.96	0.031
Middle tertile (5.6–8.0 vs ≤5.6)	0.75	0.43 – 1.33	0.33
Upper tertile (>8.0 vs ≤5.6)	3.31	1.84 – 5.95	6.8×10^{-7}

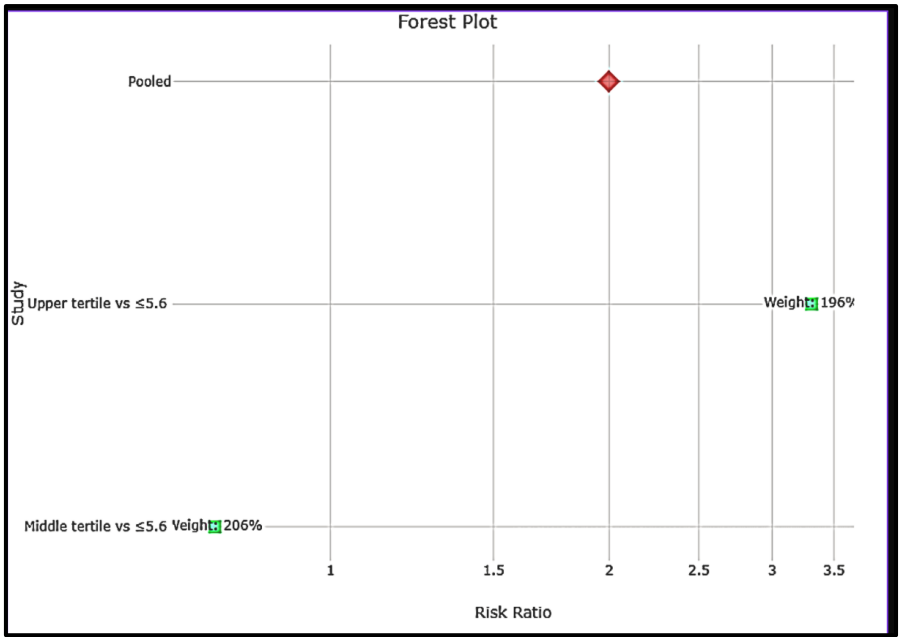

Figure 1: Forest Plot Showing Risk Ratios for Metabolic Syndrome by Albuminuria Tertiles

The forest plot displays the odds ratios (ORs) for metabolic syndrome across albuminuria tertiles compared to the lowest tertile (≤5.6 mg/L). Each green square represents the OR estimate for a tertile group, with the size of the square reflecting the weight of the data. The horizontal lines indicate the 95% confidence intervals (CI) for each estimate. The vertical dashed blue line at OR = 1 represents no difference in risk. If a confidence interval crosses this line, the result is not statistically significant. The red diamond at the top shows the pooled OR from the combined analysis, with its width indicating the 95% CI. The pooled OR and the upper tertile's OR are significantly greater than 1, indicating that individuals with higher albuminuria (>8.0 mg/L) have increased odds of metabolic syndrome, while the middle tertile shows no significant difference.

DISCUSSION

This hospital-based study revealed a significant increase in the prevalence of metabolic syndrome (MetS) with rising levels of low-grade albuminuria, reinforcing the emerging understanding of albuminuria as an early marker of endothelial dysfunction and cardiometabolic risk. We found that MetS prevalence increased sharply from 32.1% in the middle albuminuria tertile to 68.1% in the highest tertile, a finding consistent with previous reports demonstrating albuminuria's strong association with cardiovascular and metabolic abnormalities(11,12) . The elevated odds of MetS in the upper albuminuria group (OR 3.31, 95% CI: 1.84–5.95) further validate this relationship and suggest a threshold effect where albuminuria beyond a certain level significantly heightens metabolic risk. Mechanistically, albuminuria reflects increased glomerular permeability often caused by systemic endothelial damage, which is an early manifestation of metabolic dysregulation. Endothelial dysfunction not only facilitates albumin leakage into urine but also contributes to insulin resistance, hypertension, and pro-inflammatory states that are hallmarks of MetS development. This mechanistic interplay underscores the clinical value of detecting even low-grade albuminuria for early risk stratification and intervention.

Our results also highlighted significant differences in cardiometabolic parameters across albuminuria tertiles. Participants with higher albuminuria levels exhibited elevated diastolic blood pressure (DBP), fasting glucose, and triglycerides, along with reduced HDL cholesterol levels—classic components of metabolic syndrome and markers of increased cardiovascular risk. The Kruskal-Wallis analysis confirmed that fasting glucose showed the strongest statistical association ($H = 53.26$, $p < 0.001$), emphasizing albuminuria's relationship with glycemic dysregulation. This finding is in agreement with other studies that have documented a similar pattern of increasing fasting glucose and insulin resistance with rising albuminuria(13,14) .The observed decrease in HDL cholesterol and increase in waist-to-hip ratio further supports the notion that albuminuria tracks with worsening lipid metabolism and central obesity, both critical drivers of metabolic dysfunction (15-17) Mechanistically, persistent hyperglycemia and dyslipidemia may exacerbate glomerular endothelial injury through oxidative stress and inflammation, amplifying albumin leakage and creating a vicious cycle of metabolic and vascular damage . Our findings thus affirm albuminuria's role as a sensitive marker of metabolic health deterioration.

Additionally, gender distribution analysis showed a higher proportion of males in the upper albuminuria tertile, which aligns with previous observations of male

predominance in metabolic and renal risk profiles (18-19) Notably, systolic blood pressure and BMI did not differ significantly across tertiles in our cohort, which may reflect population-specific characteristics or sample size limitations. Nevertheless, the strong associations observed for DBP, fasting glucose, HDL, and waist-to-hip ratio underscore the progressive cardiometabolic impairment accompanying increased albuminuria. Taken together, these results support a mechanistic model in which low-grade albuminuria is both a consequence and contributor to endothelial dysfunction, insulin resistance, and chronic low-grade inflammation—key processes driving metabolic syndrome and its cardiovascular sequelae. Therefore, routine assessment of urinary albumin, even at low levels, may provide a valuable tool for early identification and management of individuals at heightened metabolic risk.

CONCLUSION:

This study confirms a strong association between low-grade albuminuria and metabolic syndrome, highlighting albuminuria's role as an early marker of cardiometabolic risk. Higher albuminuria levels were linked with worsened metabolic parameters such as fasting glucose, blood pressure, and lipid profiles. These findings underscore the potential of low-grade albuminuria in early risk stratification and prevention of metabolic and cardiovascular diseases. Incorporating urinary albumin screening in routine clinical assessments may improve early detection and management. Further longitudinal studies are needed to clarify causality and assess the benefits of targeted interventions to reduce albuminuria and metabolic risk.

Limitations

- Cross-sectional design limits conclusions about causality.
- Hospital-based sample may not fully represent the general population.
- Some metabolic data (e.g., BMI) were incomplete.
- Potential influence of unmeasured confounders cannot be entirely excluded.
- Slight gender imbalance with more males in higher albuminuria groups.

Advantages

- Large sample size with robust statistical analysis.
- Use of albuminuria tertiles allowed nuanced risk assessment.
- Inclusion of multiple metabolic parameters enhances findings.
- First study in this population linking low-grade albuminuria with MetS.
- Clinical relevance for early screening and risk stratification.

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