

Hematological Inflammatory Markers and Severity of Metabolic Syndrome Components among Adults with Metabolic Syndrome: A Cross-Sectional Study

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ABSTRACT

Background: Metabolic syndrome is a cluster of metabolic abnormalities associated with chronic low-grade inflammation and increased cardiovascular risk. Haematological inflammatory markers derived from routine blood counts may serve as simple indicators of systemic inflammation. Objectives: To assess the association between haematological inflammatory markers like-WBC count, neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio, and monocyte-to-lymphocyte ratio and metabolic syndrome and to evaluate their relationship with Metabolic syndrome severity.

Methods: This hospital-based cross-sectional study included 170 adults fulfilling NCEP-ATP III criteria for Metabolic syndrome. Clinical, anthropometric, and biochemical parameters were recorded. NLR, PLR, and MLR were calculated from complete blood count parameters. Statistical analysis included ANOVA, Pearson's correlation, Chi-square test, and multiple linear regression.

Results: The mean age of participants was 52.7±10.0 years, and 55.9% were females. WBC count, NLR, PLR, and MLR increased significantly with increasing number of Metabolic syndrome components ($p<0.001$). NLR showed strong positive correlations with BMI ($r=0.858$), fasting blood sugar ($r=0.984$), and triglycerides ($r=0.983$), and a strong negative correlation with HDL-C ($r=-0.989$) (all $p<0.001$).

Conclusion: The present study demonstrates that inflammatory hematological markers, particularly NLR, PLR, MLR show significant associations with increasing metabolic syndrome severity in univariate analyses, suggesting their potential role as indicators of systemic inflammation in metabolic syndrome. However, after mutual adjustment in the multivariate regression model, none of these markers emerged as independent predictors of metabolic syndrome severity.

Keywords: Metabolic syndrome, Inflammation, Neutrophils, Biomarkers, Insulin Resistance

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INTRODUCTION

Metabolic syndrome (MetS) is a group of metabolic abnormalities that collectively increase the risk of cardiovascular, cerebrovascular diseases and type 2 diabetes mellitus.[1] According to NCEP-ATP III criteria Metabolic syndrome includes components like central obesity, hyper triglyceridemia, hypertension, and impaired fasting glucose and reduced HDL-C.[2]

Increasing evidence suggests that long-standing low-grade systemic inflammation is considered a central mechanism underlying the disease process. and progression of metabolic syndrome. Inflammatory activation contributes to insulin resistance, endothelial dysfunction, and atherogenesis through cytokine-mediated pathways and adipose tissue inflammation.[3] Conventional biomarkers such as fasting blood glucose and lipid profile reflect established metabolic abnormalities but may not adequately capture the underlying inflammatory burden associated with metabolic syndrome.

Recently, hematological inflammatory markers derived from routine complete blood counts have gained increasing attention as potential indicators of systemic inflammation. Inflammatory indices such as total white blood cell count, NLR, PLR, and MLR have gained considerable attention as accessible biomarkers of systemic inflammation. Because they are inexpensive, routinely measured, and reproducible, these parameters are well suited for integration into everyday clinical practice, particularly in resource-constrained environments.[4]

Several studies have demonstrated significant associations between elevated hematological inflammatory markers and metabolic syndrome.[5,6] The study aimed to determine the prevalence of elevated inflammatory markers among adults with metabolic syndrome and to assess the association between inflammatory markers and the severity of metabolic syndrome.

MATERIALS AND METHODS

This hospital-based cross-sectional study was conducted in the Department of General Medicine at tertiary care institution after obtaining approval from the Institutional Ethics Committee. with approval no F.3/Acad/Ethical Clearance/Batch2023/2025/05. Written informed consent was obtained from all participants before enrollment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

The sample size was estimated using the standard sample size formula for single proportion. The calculated sample size was 167, with expected proportion of 12.4% based on previous studies[7], therefore 170 patients were enrolled.

A total of 170 adult who are more than 18 years and give written consent and fulfilling NCEP-ATP III criteria for metabolic syndrome were included in the study. Pregnant women, infectious, inflammatory, hematological and

immune compromised diseases were excluded.

Detailed demographic and clinical history were obtained from all participants. General and systemic examinations were performed. Blood investigations included complete blood count, fasting blood sugar, lipid profile, liver function test, and renal function test were done. Hematological parameters were measured using an automated hematology analyzer.

Inflammatory indices were calculated from complete blood count parameters. NLR was obtained by dividing the absolute neutrophil count by the absolute lymphocyte count, PLR by dividing the platelet count by the absolute lymphocyte count, and MLR by dividing the absolute monocyte count by the absolute lymphocyte count.

All data were entered into and analyzed using IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as mean $\pm$ standard deviation (SD), whereas categorical variables were expressed as frequencies and percentages. Comparisons of continuous variables across metabolic syndrome severity groups were performed using one-way analysis of variance (ANOVA). Associations between inflammatory hematological markers and metabolic syndrome severity were assessed using Pearson's correlation coefficient. To evaluate the independent association of inflammatory hematological markers with metabolic syndrome severity, multiple linear regression analysis was performed after adjustment for age, sex, body mass index (BMI), smoking status, and alcohol consumption. Owing to the potential for multicollinearity among WBC, NLR, PLR, and MLR, each inflammatory marker was entered into a separate regression model. A two-tailed p -value of <0.05 was considered statistically significant.

RESULTS

The mean age of participants was 52.7 ± 10.0 years. Most participants belonged to the 51–60 years age group (33.5%). Females constituted 55.9% of the study population. The mean BMI was 27.4 ± 6.08 kg/m², indicating predominance of overweight individuals. Most participants were non-smokers (77.1%) and non-alcoholic (85.9%). (Table-1)

Table-1: Basic Characteristics of study population

Characteristics	Participants (%)
Age	
30-40	24 (14.1)
41-50	46 (27.1)
51-60	57 (33.5)
>60	43 (25.3)
Mean Age	52.7 $\pm$ 10
Sex	
Female	95 (55.9)
Male	75 (44.1)
Mean BMI $\pm$ sd	27.4 $\pm$ 6.08
Substance use	
smoking	39 (22.9)
Alcohol	24 (14.1)

Table 2: Parameters according to number of metabolic syndrome components

Parameters	3 components	4 components	5 components	p value
BMI	24.9 ± 4.3	29.6 ± 5.1	33.8 ± 3.2	<0.001
Waist circumference	87.6 ± 8.9	96.8 ± 7.6	104 ± 6.5	<0.001
Systolic BP	126.8 ± 9.4	140.9 ± 11.2	157.6 ± 6.8	<0.001
Diastolic BP	79.8 ± 5.8	88.6 ± 6.7	97.8 ± 3.9	<0.001
Fasting blood sugar	112.8 ± 9.6	148.6 ± 13.2	167.9 ± 6.8	<0.001
Triglyceride	168.6 ± 18.4	224.8 ± 24.6	274.2 ± 12.8	<0.001
HDL-c	43.2 ± 2.8	38.6 ± 2.6	33.4 ± 1.6	<0.001
WBC	6.9 ± 0.4	8.2 ± 0.5	9 ± 0.3	<0.001
Neutrophil	3.9 ± 0.5	4.6 ± 0.4	5.3 ± 0.3	<0.001
Lymphocyte	2.3 ± 0.2	2.1 ± 0.2	1.9 ± 0.1	<0.001
Monocyte	0.57 ± 0.07	0.58 ± 0.08	0.60 ± 0.08	<0.001
*NLR	1.72 ± 0.18	2.32 ± 0.26	2.96 ± 0.22	<0.001
*PLR	122.6 ± 12.4	156.8 ± 15.6	184.2 ± 8.9	<0.001
*MLR	0.23 ± 0.03	0.29 ± 0.03	0.39 ± 0.02	<0.001

*NLR/PLR/MLR calculated as mean of ratio

Table 3: Correlation of Neutrophil-Lymphocyte Ratio (NLR) with Metabolic Variables

Variable	Pearson's Correlation Coefficient (r)	p-value
BMI (kg/m ²)	+0.858	<0.001
FBS (mg/dL)	+0.984	<0.001
Triglycerides (mg/dL)	+0.983	<0.001
HDL-C (mg/dL)	-0.989	<0.001

Table 4: Adjusted multivariable linear regression analyses for inflammatory hematological markers and metabolic syndrome severity

Model	Variable	Standardized Beta (β)	p-value
Model 1	NLR	0.324	0.117
Model 2	PLR	0.006	0.101
Model 3	MLR	2.336	0.112
Model 4	Total WBC Count	0.168	0.180

Note: Each model was adjusted for age, sex, BMI, smoking status, and alcohol consumption.

Among the study participants, 42.4% had three metabolic syndrome components, 37.6% had four components, and 20.0% had all five components.

BMI and waist circumference increased significantly with increasing number of metabolic syndrome components ($p < 0.001$). Mean BMI increased from 24.9 ± 4.3 kg/m² in participants with three components to 33.8 ± 3.2 kg/m² in those with five components. Both systolic and diastolic blood pressure demonstrated progressive rise with increasing metabolic syndrome severity ($p < 0.001$). A progressive increase in fasting blood glucose and triglyceride levels, accompanied by a significant reduction in HDL-C levels, was observed as the number of metabolic syndrome components increased. ($p < 0.001$).

Total WBC count increased progressively from $6.9 \pm 0.4 \times 10^3/\mu\text{L}$ in participants with three components to $9.0 \pm 0.3 \times 10^3/\mu\text{L}$ in participants with five components ($p < 0.001$). Neutrophil counts increased significantly while lymphocyte counts decreased significantly with increasing metabolic syndrome severity. Mean NLR increased from 1.72 ± 0.18 in participants with three com-

ponents to 2.96 ± 0.22 in those with five components ($p < 0.001$). Similarly, PLR increased from 122.6 ± 12.4 to 184.2 ± 8.9 , while MLR increased from 0.23 ± 0.03 to 0.39 ± 0.02 with increasing metabolic syndrome components ($p < 0.001$). (Table-2)

NLR demonstrated strong positive correlations with BMI ($r = +0.858$), fasting blood sugar ($r = +0.984$), and triglycerides ($r = +0.983$). A strong negative correlation was observed between NLR and HDL-C ($r = -0.989$). (Table-3)

None of the inflammatory markers demonstrated an independent association with metabolic syndrome severity after adjusted (Adjustment for age, sex, BMI, smoking and alcohol, to minimize multicollinearity arising from the overlapping derivation of WBC, NLR, PLR, and MLR) multivariable linear regression analyses for inflammatory hematological markers and metabolic syndrome severity (Table-4)

Although significant associations between inflammatory hematological markers and metabolic syndrome severity were observed in the univariate analyses. This apparent discordance suggests that the observed univariate relationships were partly influenced by shared variance with clinical covariates and by intercorrelation among the inflammatory markers. Consequently, after adjustment, no single hematological marker demonstrated an independent association with metabolic syndrome severity.

DISCUSSION

The present study investigated the association between hematological inflammatory markers and metabolic syndrome in adults attending a tertiary care center. The findings demonstrated that inflammatory indices increased progressively with increasing clustering of metabolic syndrome components, supporting the concept that chronic systemic inflammation is closely linked with metabolic dysfunction.

Most participants belonged to the middle-aged and elderly age groups, indicating that metabolic syndrome becomes increasingly common with advancing age,

Similar age predominance has been observed by Sarrafan-Chaharsoughi Z et al.[8]

Female predominance observed in the present study may be related to higher rates of central obesity, hormonal influences, and lifestyle-related metabolic risk factors. This female predominance is consistent with findings reported by Najafzadeh MJ et al.[4]

Anthropometric parameters such as BMI and waist circumference showed significant progressive elevation with increasing number of metabolic syndrome components. Similar trends were observed for blood pressure, fasting blood sugar, and triglyceride levels, whereas HDL-C levels declined significantly. These findings reinforce the established relationship between obesity, insulin resistance, dyslipidemia, and cardiometabolic risk. Najafzadeh MJ et al.[4] and Sarrafan-Chaharsoughi Z et al.[8] Demonstrated similar findings in their studies.

A major observation of the present study was the consistent increase in hematological inflammatory markers including total WBC count, NLR, PLR, and MLR with worsening metabolic syndrome severity, which is similar to findings of Bahadir A et al.[5] Elevated neutrophil counts along with relative reduction in lymphocyte suggest enhanced inflammatory activation and immune imbalance in individuals with greater metabolic burden.

Similar to observation by Najafzadeh MJ et al.[4] and Bahadir A et al.[5] in this study, among all inflammatory indices, NLR demonstrated the strongest association with metabolic parameters. Significant positive correlations were observed between NLR and BMI, fasting blood sugar, and triglyceride levels, while HDL-C showed a strong inverse relationship. These findings indicate that NLR may reflect both inflammatory activity and metabolic deterioration in patients with metabolic syndrome.

PLR and MLR also showed significant elevation with increasing metabolic syndrome components. These findings are consistent with the observation by Yang Y et al.[9] Platelet activation contributes to endothelial dysfunction and vascular inflammation, whereas monocyte-mediated inflammatory pathways play an important role in atherosclerosis and insulin resistance. Therefore, these indices may provide additional insight into the inflammatory status of affected individuals.

An important finding of the present study is the difference between the univariate and multivariable analyses. Although inflammatory hematological markers showed significant correlations with increasing metabolic syndrome severity, these associations were no longer statistically significant after adjustment for potential confounders. This finding suggests that the observed univariate associations may partly reflect the influence of demographic and clinical characteristics rather than independent effects of the hematological markers themselves. In addition, inflammatory indices such as WBC, NLR, PLR, and MLR are biologically related and may exhibit multicollinearity, which can reduce the precision of regression coefficients and diminish statistical signifi-

cance despite significant univariate associations. Therefore, these markers may be more useful as indicators of the overall inflammatory milieu associated with metabolic syndrome rather than as independent predictors of disease severity. Future multicenter studies with larger sample sizes and external validation are warranted to further evaluate their independent prognostic value.

LIMITATIONS

The cross-sectional design of the study precludes the establishment of causal relationships. In addition, the single-center setting and relatively small sample size may limit the generalizability of the findings. Advanced inflammatory biomarkers such as CRP and cytokine assays were not evaluated in this study. Only participants with metabolic syndrome were enrolled, the absence of a non-metabolic syndrome comparison group limited our ability to compare inflammatory hematological markers between individuals with and without metabolic syndrome. Also, Long-term cardiovascular outcomes were not assessed in this study.

CONCLUSION

The present study demonstrates that hematological inflammatory markers including total WBC count, NLR, PLR, and MLR are significantly associated with metabolic syndrome severity and adverse metabolic parameters. Among the evaluated markers, NLR showed the strongest correlations with metabolic abnormalities including fasting blood sugar, triglycerides, BMI, and HDL-C. These findings suggest that hematological inflammatory markers may serve as simple, inexpensive, and readily available adjunctive tools for identifying inflammatory burden and cardiometabolic risk in patients with metabolic syndrome. Further large-scale prospective studies are recommended to validate the prognostic utility of these markers and establish their role in routine metabolic risk stratification.

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Availability of data: The data that support the findings of this study are available from the corresponding author on reasonable request.

Declaration of Non-use of generative AI Tools: This article was prepared without the use of generative AI tools for content creation, analysis, or data generation. All findings and interpretations are based solely on the authors' independent work and expertise.

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