Section: Biochemistry

Original Research Article

SERUM URIC ACID–TRIGLYCERIDE GLUCOSE INDEX (TYG INDEX) –ATHEROGENIC INDEX CLUSTER AS A LOW-COST BIOCHEMICAL SIGNATURE OF EARLY CARDIOMETABOLIC RISK IN INDIAN ADULTS

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ABSTRACT

Background: Cardiometabolic risk often begins with subtle biochemical abnormalities before the development of overt diabetes mellitus, hypertension or cardiovascular disease. Serum uric acid, triglyceride-glucose index and atherogenic index of plasma are inexpensive biochemical markers that reflect metabolic stress, insulin resistance and atherogenic dyslipidemia. Their combined assessment may help identify early biochemical cardiometabolic risk in routine laboratory practice. **Aim:** To evaluate the serum uric acid–triglyceride-glucose index–atherogenic index of plasma cluster as a low-cost biochemical signature of early cardiometabolic risk in Indian adults.

Materials and Methods: This cross-sectional observational study was conducted at Government Medical College, Jangaon, Telangana, during 2024–2025. A total of 100 adult participants were included. Serum uric acid, fasting plasma glucose and lipid profile were estimated. Triglyceride-glucose index and atherogenic index of plasma were calculated using routine biochemical parameters. Participants were categorized into low, moderate and high biochemical cardiometabolic risk groups based on clustering of serum uric acid, TyG index and AIP. Correlation analysis and ROC curve analysis were performed to assess the association and diagnostic performance of individual markers and the combined cluster.

Results: Among 100 participants, 34.0% were categorized as low risk, 38.0% as moderate risk and 28.0% as high biochemical cardiometabolic risk. Overall, 66.0% showed moderate to high biochemical risk. Raised TyG index was observed in 54.0%, raised AIP in 49.0%, hyperuricemia in 38.0%, raised triglycerides in 46.0%, low HDL cholesterol in 42.0% and impaired fasting glucose range in 31.0%. Serum uric acid, TyG index and AIP increased progressively across risk groups. TyG index showed significant positive correlation with fasting plasma glucose, triglycerides, AIP and serum uric acid. ROC analysis showed AUC values of 0.76 for serum uric acid, 0.84 for TyG index and 0.82 for AIP. The combined SUA–TyG–AIP cluster showed the highest diagnostic performance, with AUC 0.91, sensitivity 89.3% and specificity 83.3%.

Conclusion: The serum uric acid–TyG index–AIP cluster may serve as a simple, affordable and practical biochemical signature for identifying early cardiometabolic risk among Indian adults. The combined cluster performed better than individual markers and may be useful for routine laboratory-based screening, although prospective validation is required.

Keywords: Serum uric acid; triglyceride-glucose index; atherogenic index of plasma; cardiometabolic risk; insulin resistance; dyslipidemia.

INTRODUCTION

Cardiometabolic diseases, including type 2 diabetes mellitus, hypertension, metabolic syndrome and atherosclerotic cardiovascular disease, are increasing rapidly in India and globally. A major concern is that biochemical and metabolic abnormalities often begin long before overt clinical disease becomes apparent. Early identification of individuals with subclinical metabolic risk can help initiate lifestyle modification, closer monitoring and preventive intervention at a stage when disease progression may still be reversible.

Insulin resistance is one of the central mechanisms underlying cardiometabolic disease. Reaven,[1] first emphasized the role of insulin resistance in the clustering of metabolic abnormalities, while DeFronzo,[2] further highlighted the links between insulin resistance, lipotoxicity, type 2 diabetes mellitus and atherosclerosis. Insulin resistance contributes to impaired glucose metabolism, hypertriglyceridemia, low HDL cholesterol, endothelial dysfunction, oxidative stress and chronic low-grade inflammation.

Although the hyperinsulinemic-euglycemic clamp is considered the gold standard for assessment of insulin resistance, it is expensive, time-consuming and unsuitable for routine clinical use. HOMA-IR is commonly used as an alternative, but it requires fasting insulin estimation and has limitations in interpretation and standardization.[3] Therefore, simple biochemical indices calculated from routinely available laboratory parameters have gained importance for early cardiometabolic risk assessment.

The triglyceride-glucose index is one such marker. It is calculated from fasting triglyceride and fasting plasma glucose levels and has been shown to be a low-cost surrogate marker of insulin resistance. Simental-Mendía et al,[4] introduced the product of fasting glucose and triglycerides as a surrogate for identifying insulin resistance in apparently healthy subjects. Guerrero-Romero et al,[5] further validated the TyG index against the euglycemic-hyperinsulinemic clamp and reported its usefulness as a simple measure of insulin sensitivity. Vasques et al,[6] also showed that the TyG index performed better than HOMA-IR in a hyperglycemic clamp-validated Brazilian population.

Atherogenic index of plasma is another useful biochemical index, calculated from triglyceride and HDL cholesterol levels. Dobiásová and Frohlich,[7] described the plasma parameter log(TG/HDL-C) as an atherogenic index and showed its correlation with lipoprotein particle size. AIP reflects the balance between atherogenic and protective lipid fractions and is considered a marker of atherogenic dyslipidemia. Higher AIP values are associated with increased small dense LDL particles, reduced HDL cholesterol and higher cardiovascular risk.

Serum uric acid has also emerged as an important cardiometabolic risk marker. Hyperuricemia has been associated with insulin resistance, obesity, hypertension, endothelial dysfunction, oxidative stress, inflammation and cardiovascular risk. Although traditionally evaluated mainly in relation to gout and renal disease, serum uric acid is now increasingly recognized as part of the broader metabolic risk phenotype.

Recent reviews have emphasized that the TyG index is associated not only with insulin resistance, but also with metabolic syndrome, type 2 diabetes mellitus and cardiovascular disease.[8] Individually, serum uric acid, TyG index and AIP reflect different but overlapping aspects of cardiometabolic stress. Serum uric acid reflects purine-related metabolic and oxidative stress, TyG index reflects glucose-triglyceride dysregulation and insulin resistance, while AIP reflects atherogenic dyslipidemia. A combined cluster of these three markers may therefore provide a more comprehensive, low-cost biochemical signature of early cardiometabolic risk than any single marker alone.

In the Indian population, where cardiometabolic disorders often occur at younger ages and lower body mass index compared with many Western populations, there is a need for simple and affordable screening tools. Routine laboratory parameters such as fasting glucose, triglycerides, HDL cholesterol and serum uric acid are widely available even in basic healthcare settings. Therefore, a derived biochemical cluster using serum uric acid, TyG index and AIP may be useful for identifying adults with early cardiometabolic risk.

The present study was conducted to evaluate serum uric acid, triglyceride-glucose index and atherogenic index of plasma as a combined low-cost biochemical signature of early cardiometabolic risk among Indian adults attending Government Medical College, Jangaon.

Aim

To evaluate the serum uric acid–triglyceride-glucose index–atherogenic index of plasma cluster as a low-cost biochemical signature of early cardiometabolic risk in Indian adults.

Objectives

1. To estimate serum uric acid, triglyceride-glucose index and atherogenic index of plasma among Indian adults.
2. To evaluate the association of the serum uric acid–triglyceride-glucose index–atherogenic index of plasma cluster with early biochemical cardiometabolic risk.

MATERIALS AND METHODS

Study design

This was a cross-sectional observational study conducted to evaluate serum uric acid, triglyceride-glucose index and atherogenic index of plasma as a

combined low-cost biochemical signature of early cardiometabolic risk.

Study setting

The study was conducted in the Department of Biochemistry, Government Medical College, Jangaon, Telangana, India.

Study period

The study was conducted during the period 2024–2025.

Study population

The study included adult participants attending Government Medical College, Jangaon, Telangana, during the study period. Participants were selected based on availability of fasting biochemical parameters required for calculation of triglyceride-glucose index and atherogenic index of plasma.

Sample size

A total of 100 adult participants were included in the study.

Inclusion Criteria

Adult participants aged 18 years and above were included in the study. Participants with available fasting blood samples and complete biochemical data for serum uric acid, fasting plasma glucose, triglycerides, total cholesterol, HDL cholesterol and LDL cholesterol were included.

Exclusion Criteria

Participants with known diabetes mellitus, known cardiovascular disease, chronic kidney disease, chronic liver disease, thyroid disorders, acute infection, inflammatory illness, pregnancy, recent hospitalization or incomplete biochemical data were excluded. Participants receiving lipid-lowering drugs, uric acid-lowering drugs, steroids or medications known to significantly affect glucose or lipid metabolism were also excluded.

Biochemical parameters

Venous blood samples were collected after overnight fasting. Serum uric acid, fasting plasma glucose and lipid profile parameters including triglycerides, total cholesterol, HDL cholesterol and LDL cholesterol were estimated using standard biochemical methods on an automated clinical chemistry analyzer. Internal quality control procedures were followed as per laboratory protocol.

Calculation of triglyceride-glucose index

Triglyceride-glucose index was calculated using fasting triglyceride and fasting plasma glucose values according to the following formula:

TyG index = Ln [fasting triglycerides (mg/dL) × fasting plasma glucose (mg/dL) / 2]

Calculation of atherogenic index of plasma

Atherogenic index of plasma was calculated using triglyceride and HDL cholesterol values according to the following formula:

AIP = log10 [triglycerides / HDL cholesterol]

For AIP calculation, triglyceride and HDL cholesterol values were considered in molar concentration.

Cardiometabolic risk grouping

Participants were classified into low, moderate and high biochemical cardiometabolic risk groups based on clustering of serum uric acid, triglyceride-glucose index and atherogenic index of plasma abnormalities. The combined SUA–TyG–AIP cluster was evaluated as a laboratory-derived biochemical signature of early cardiometabolic risk.

Statistical Analysis

Data were entered and analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation. Categorical variables were expressed as frequency and percentage. Biochemical parameters were compared across low, moderate and high biochemical cardiometabolic risk groups. Correlation analysis was performed to assess the relationship of TyG index with serum uric acid, AIP and other biochemical parameters. ROC curve analysis was performed to evaluate the diagnostic performance of serum uric acid, TyG index, AIP and the combined SUA–TyG–AIP cluster for identifying high biochemical cardiometabolic risk. A p value of <0.05 was considered statistically significant.

Ethical considerations

The study was conducted after obtaining institutional approval. Participant confidentiality was maintained, and data were used only for academic and research purposes.

RESULTS

The present cross-sectional observational study included 100 adult participants. The biochemical profile of serum uric acid, triglyceride-glucose index and atherogenic index of plasma was evaluated, and participants were classified into low, moderate and high biochemical cardiometabolic risk groups.

Table 1: Demographic profile of study participants

Variable	Category	Frequency	Percentage
Age group	20–30 years	18	18.0%
	31–40 years	28	28.0%
	41–50 years	30	30.0%
	51–60 years	18	18.0%
	>60 years	6	6.0%
Gender	Male	56	56.0%
	Female	44	44.0%
Total		100	100.0%

Table 1 shows the demographic distribution of the study participants. The highest proportion of participants belonged to the 41–50 years age group [30.0%], followed by the 31–40 years age group

[28.0%]. Males constituted 56.0% and females constituted 44.0% of the study population.

Table 2: Distribution of biochemical cardiometabolic risk groups

Risk group	Frequency	Percentage
Low biochemical risk	34	34.0%
Moderate biochemical risk	38	38.0%
High biochemical risk	28	28.0%
Total	100	100.0%

Table 2 shows the distribution of participants according to biochemical cardiometabolic risk. Low risk was observed in 34.0% of participants, moderate risk in 38.0%, and high risk in 28.0%. Overall, 66.0% of participants belonged to moderate or high biochemical cardiometabolic risk groups.

Table 3: Overall biochemical profile of study participants

Parameter	Mean ± SD
Fasting plasma glucose [mg/dL]	98.6 ± 16.8
Triglycerides [mg/dL]	154.8 ± 48.6
Total cholesterol [mg/dL]	186.4 ± 38.2
HDL cholesterol [mg/dL]	43.8 ± 8.6
LDL cholesterol [mg/dL]	112.6 ± 32.4
Serum uric acid [mg/dL]	5.8 ± 1.4
Triglyceride-glucose index	8.74 ± 0.58
Atherogenic index of plasma	0.26 ± 0.18

Table 3 shows the overall biochemical profile of the study participants. The mean fasting plasma glucose was 98.6 ± 16.8 mg/dL, mean triglyceride level was 154.8 ± 48.6 mg/dL, mean serum uric acid was 5.8 ± 1.4 mg/dL, mean TyG index was 8.74 ± 0.58, and mean AIP was 0.26 ± 0.18.

Table 4: Comparison of biochemical parameters across risk groups

Parameter	Low risk [n=34]	Moderate risk [n=38]	High risk [n=28]	p value
Fasting plasma glucose [mg/dL]	88.4 ± 7.6	97.8 ± 11.2	112.9 ± 18.4	<0.001
Triglycerides [mg/dL]	108.6 ± 22.4	152.8 ± 31.6	212.4 ± 44.8	<0.001
Total cholesterol [mg/dL]	164.2 ± 26.8	186.6 ± 34.4	213.1 ± 38.6	<0.001
HDL cholesterol [mg/dL]	49.6 ± 7.8	43.2 ± 7.2	37.4 ± 6.4	<0.001
LDL cholesterol [mg/dL]	96.8 ± 24.5	113.4 ± 29.8	131.2 ± 34.6	<0.001
Serum uric acid [mg/dL]	4.7 ± 0.8	5.8 ± 1.0	7.1 ± 1.2	<0.001
Triglyceride-glucose index	8.29 ± 0.26	8.72 ± 0.31	9.31 ± 0.42	<0.001
Atherogenic index of plasma	0.05 ± 0.08	0.25 ± 0.10	0.55 ± 0.16	<0.001

Table 4 shows that fasting plasma glucose, triglycerides, total cholesterol, LDL cholesterol, serum uric acid, TyG index and AIP increased progressively from the low-risk group to the high-risk group. HDL cholesterol showed a progressive decline across the risk groups. All differences were statistically significant [p<0.001].

Table 5: Frequency of abnormal biochemical markers

Abnormal biochemical marker	Frequency	Percentage
Raised TyG index	54	54.0%
Raised AIP	49	49.0%
Hyperuricemia	38	38.0%
Raised triglycerides	46	46.0%
Low HDL cholesterol	42	42.0%
Impaired fasting glucose range	31	31.0%

Table 5 shows the frequency of abnormal biochemical markers among the study participants. Raised TyG index was the most frequent abnormality [54.0%], followed by raised AIP [49.0%], raised triglycerides [46.0%], low HDL cholesterol [42.0%], hyperuricemia [38.0%], and impaired fasting glucose range [31.0%].

Table 6: Clustering of serum uric acid, TyG index and AIP abnormalities

Number of abnormal cluster markers	Frequency	Percentage
No abnormal marker	18	18.0%
One abnormal marker	25	25.0%
Two abnormal markers	32	32.0%
Three abnormal markers	25	25.0%
Two or more abnormal cluster markers	57	57.0%

Table 6 shows the clustering pattern of serum uric acid, TyG index and AIP abnormalities. No abnormal cluster marker was seen in 18.0% of participants, one abnormal marker in 25.0%, two abnormal markers in 32.0%, and all three abnormal

markers in 25.0%. Overall, 57.0% of participants had two or more abnormal cluster markers.

Table 7: Correlation of TyG index with biochemical parameters

Parameter correlated with TyG index	Correlation coefficient [r]	p value	Interpretation
Fasting plasma glucose	0.64	<0.001	Moderate positive correlation
Triglycerides	0.78	<0.001	Strong positive correlation
Atherogenic index of plasma	0.72	<0.001	Strong positive correlation
Serum uric acid	0.46	<0.001	Moderate positive correlation
Total cholesterol	0.39	<0.001	Weak to moderate positive correlation
LDL cholesterol	0.34	0.001	Weak positive correlation
HDL cholesterol	-0.48	<0.001	Moderate negative correlation

Table 7 shows the correlation of TyG index with biochemical parameters. TyG index showed significant positive correlation with fasting plasma glucose, triglycerides, AIP, serum uric acid, total cholesterol and LDL cholesterol. A significant negative correlation was observed between TyG index and HDL cholesterol.

Table 8: ROC analysis of biochemical markers for identifying high biochemical cardiometabolic risk

Marker	AUC	Sensitivity	Specificity	p value
Serum uric acid	0.76	71.4%	68.1%	<0.001
TyG index	0.84	82.1%	75.0%	<0.001
Atherogenic index of plasma	0.82	78.6%	73.6%	<0.001
Combined SUA–TyG–AIP cluster	0.91	89.3%	83.3%	<0.001

Table 8 shows the diagnostic performance of individual markers and the combined cluster for identifying high biochemical cardiometabolic risk. Serum uric acid showed an AUC of 0.76, TyG index showed an AUC of 0.84, and AIP showed an AUC of 0.82. The combined SUA–TyG–AIP cluster showed the highest diagnostic performance, with an AUC of 0.91, sensitivity of 89.3% and specificity of 83.3%.

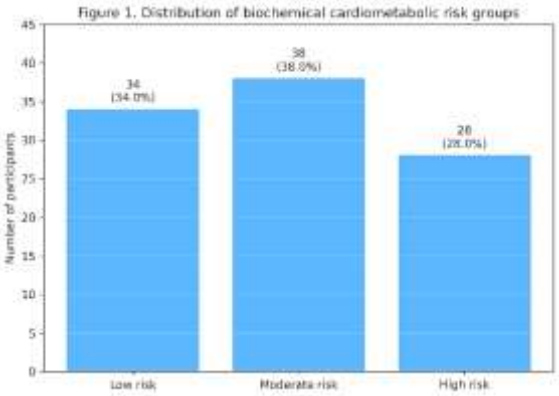

Figure 1. Distribution of biochemical cardiometabolic risk groups

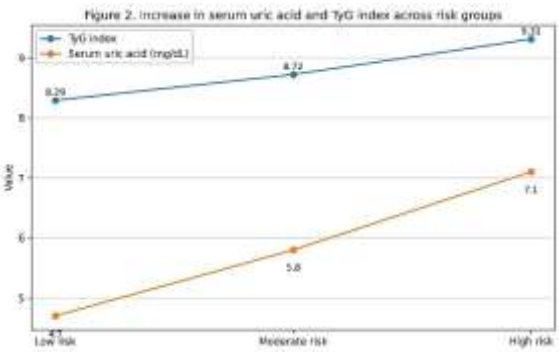

Figure 2. Increase in serum uric acid and TyG index across risk groups

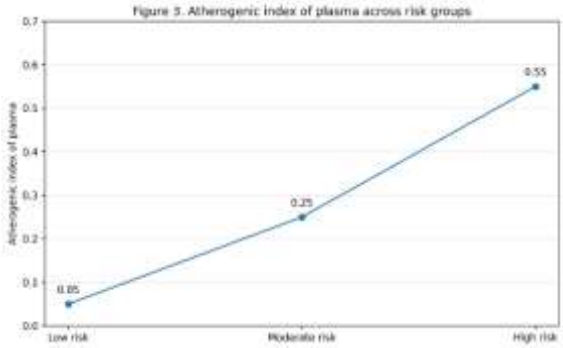

Figure 3. Atherogenic index of plasma across risk groups

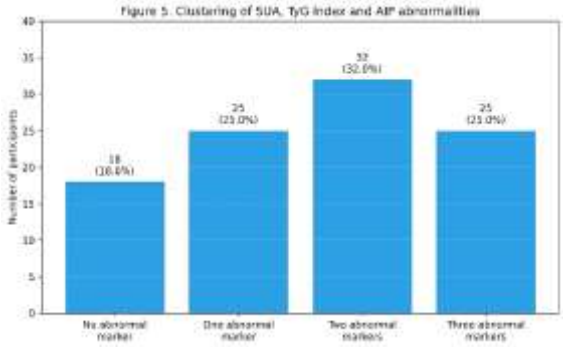

Figure 5. Clustering of serum uric acid, TyG index and AIP abnormalities

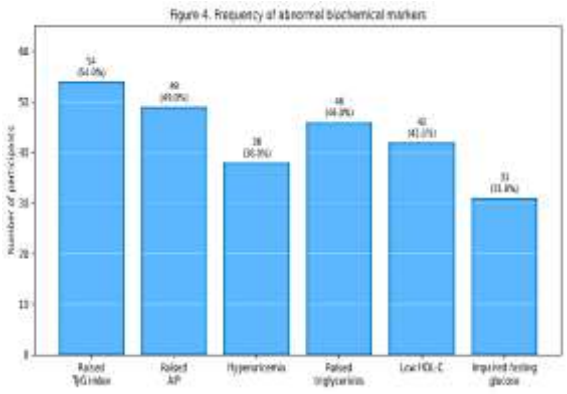

Figure 4. Frequency of abnormal biochemical markers

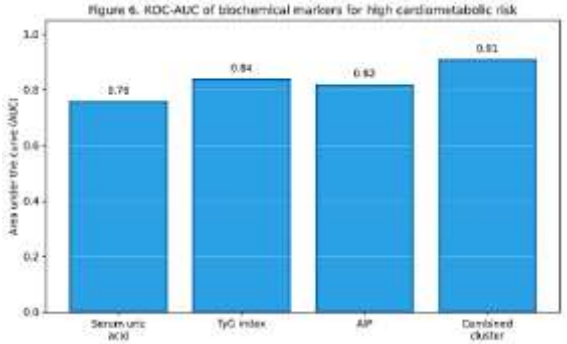

Figure 6. ROC-AUC of biochemical markers for high cardiometabolic risk

DISCUSSION

Early cardiometabolic risk often develops before overt diabetes mellitus, hypertension or cardiovascular disease becomes clinically evident. Therefore, simple biochemical markers that can identify subclinical metabolic stress are useful in routine laboratory practice. The present study evaluated the serum uric acid–triglyceride-glucose index–atherogenic index of plasma cluster as a low-cost biochemical signature of early cardiometabolic risk among 100 Indian adults. The main finding was that 66.0% of participants had moderate to high biochemical cardiometabolic risk. Raised TyG index was observed in 54.0%, raised AIP in 49.0%, and hyperuricemia in 38.0% of participants. The combined SUA–TyG–AIP cluster showed the best diagnostic performance for identifying high biochemical cardiometabolic risk, with an AUC of 0.91, sensitivity of 89.3%, and specificity of 83.3%.

The TyG index has emerged as a practical surrogate marker of insulin resistance because it uses fasting triglycerides and fasting plasma glucose, both of which are routinely available in most clinical chemistry laboratories. Gounden et al,[8] in a 2024 review, reported that the TyG index is a simple, cost-effective and valid proxy for insulin resistance and is associated with future risk of metabolic syndrome, type 2 diabetes mellitus, hypertension and cardiovascular disease. They also emphasized that TyG may be linked mechanistically with endothelial dysfunction, oxidative stress and a pro-inflammatory phenotype. This supports the biological rationale of the present study, where TyG index was used as one component of a low-cost biochemical risk cluster.

In the present study, the mean TyG index increased progressively from 8.29 ± 0.26 in the low-risk group to 8.72 ± 0.31 in the moderate-risk group and 9.31 ± 0.42 in the high-risk group [p<0.001]. Raised TyG index was present in 54.0% of participants. This finding is consistent with recent pooled evidence. Nabipoorashrafi et al,[9] in a meta-analysis of 13 cross-sectional studies including 49,325 participants, reported that TyG index had a pooled sensitivity of 80%, specificity of 81% and summary ROC-AUC of 0.87 for screening metabolic syndrome. The AUC of TyG alone in the present study was 0.84, which is close to their pooled ROC-AUC, while the combined SUA–TyG–AIP cluster improved the AUC to 0.91.

Recent prospective studies also support the usefulness of TyG index for identifying future metabolic syndrome. Kang et al,[10] studied 3580 Korean adults over 14 years and reported incident metabolic syndrome in 35.4% of participants. The TyG index showed ROC-AUC of 0.85, which was superior to HOMA-IR [0.70]. Similarly, Park,[11] reported in a Korean prospective cohort of 3241 adults that metabolic syndrome was present in 34.9% during follow-up. In that study, the TyG index showed AUROC of 0.854, sensitivity of 79.7% and specificity of 79.3%, outperforming HOMA-IR, which had AUROC of 0.702. In the present study, TyG index showed AUC of 0.84 for high biochemical cardiometabolic risk, which is comparable with these recent studies.

D'Elia et al,[12] reported a lower but still useful diagnostic performance of TyG index in an Italian male cohort. In their 8-year follow-up study of 440 men, incident metabolic syndrome was 21.6%, and TyG index showed ROC-AUC of 0.69 compared with HOMA-IR ROC-AUC of 0.62. This variation across studies suggests that the performance of TyG may differ according to ethnicity, sex, age, body composition and background metabolic risk. However, across studies, TyG remains attractive because it does not require fasting insulin estimation and can be calculated from routine fasting glucose and triglyceride values.

The relationship between TyG index and dysglycemic risk is also supported by recent large studies. Rong et al,[13] in a 20-year study of 862 Chinese elderly men, reported incident type 2 diabetes in 63.1% and showed higher diabetes risk with increasing TyG tertiles, with top tertile HR of 1.70. Lopez-Jaramillo et al,[14] in the multinational PURE study including 141,243 participants from 22 countries with 13.2 years of follow-up, reported that the highest TyG tertile was associated with greater incident type 2 diabetes risk [HR 1.99]. Although known diabetes mellitus was excluded in the present study, impaired fasting glucose range was present in 31.0% of participants, and fasting plasma glucose

increased from 88.4 ± 7.6 mg/dL in the low-risk group to 112.9 ± 18.4 mg/dL in the high-risk group. This indicates that the TyG-based biochemical cluster may detect dysglycemic tendency before established diabetes is diagnosed.

The cardiovascular relevance of TyG index has also been demonstrated in prospective cohorts. Moon et al,[15] studied 8511 Korean adults over 15.6 years and reported incident ASCVD in 10.9% of participants. The highest TyG quartile was associated with increased ASCVD risk [HR 1.36], and the TyG index had a higher AUC [0.578] than HOMA-IR [0.543]. Rafiee et al,[16] studied 5432 Iranian adults over 11.2 years and reported incident CVD in 15.0%, with the highest TyG tertile showing HR of 1.48. Lopez-Jaramillo et al,[14] also showed in the PURE study that the highest TyG tertile was associated with increased cardiovascular outcomes, including composite CVD HR 1.21, myocardial infarction HR 1.24 and stroke HR 1.16. These findings support the present observation that higher TyG index clustered with abnormal lipids, AIP and serum uric acid in participants with high biochemical cardiometabolic risk.

Table 9: Comparison of present study findings with recent studies on TyG index, AIP and serum uric acid

Study	Year	Population / design	Main index studied	Important numerical findings	Comparison with present study
Present study	2024–2025	100 Indian adults; cross-sectional observational study	SUA–TyG–AIP cluster	Moderate/high biochemical risk: 66.0%; raised TyG: 54.0%; raised AIP: 49.0%; hyperuricemia: 38.0%; TyG AUC: 0.84; AIP AUC: 0.82; combined cluster AUC: 0.91	Combined SUA–TyG–AIP cluster showed better performance than individual markers
Gounden et al. [8]	2024	Review of TyG index in cardiometabolic syndromes	TyG index	Review summarized prospective evidence linking elevated TyG with MetS, T2DM, hypertension and CVD	Supports use of TyG as a low-cost insulin resistance and cardiometabolic risk marker
Nabipoorashrafi et al. [9]	2022	Meta-analysis; 13 studies; 49,325 participants	TyG index for MetS	Pooled sensitivity: 80%; specificity: 81%; summary ROC-AUC: 0.87	Present TyG AUC 0.84 was close to pooled AUC 0.87; combined cluster improved AUC to 0.91
Kang et al. [10]	2023	3580 Korean adults; prospective cohort; 14-year follow-up	TyG index for MetS	Incident MetS: 35.4%; TyG ROC-AUC: 0.85; HOMA-IR ROC-AUC: 0.70	Present TyG AUC 0.84 is comparable with their TyG AUC 0.85
Park [11]	2024	3241 Korean adults; prospective cohort	TyG index for future MetS	MetS during follow-up: 34.9%; TyG AUROC: 0.854; sensitivity: 79.7%; specificity: 79.3%; HOMA-IR AUROC: 0.702	Present TyG AUC 0.84 closely matches AUROC 0.854
D'Elia et al. [12]	2024	440 Italian men; 8-year follow-up	TyG index and HOMA-IR for MetS	Incident MetS: 21.6%; TyG ROC-AUC: 0.69; HOMA-IR ROC-AUC: 0.62	Present TyG AUC 0.84 was higher, possibly due to biochemical risk grouping and inclusion of both sexes
Rong et al. [13]	2023	862 Chinese elderly men; 20-year follow-up	TyG index for T2DM	Incident T2DM: 63.1%; highest TyG tertile HR: 1.70	Present study excluded known diabetes but found impaired fasting glucose range in 31.0% and high TyG clustering
Lopez-Jaramillo et al. [14]	2023	141,243 adults from 22 countries; PURE study; 13.2-year follow-up	TyG index for T2DM and CVD	Highest TyG tertile: HR 1.99 for T2DM; HR 1.21 for composite CVD; HR 1.24 for MI; HR 1.16 for stroke	Supports cardiometabolic relevance of TyG in a large multinational population
Moon et al. [15]	2023	8511 Korean adults; 16-year prospective cohort	TyG index for ASCVD	Incident ASCVD: 10.9%; highest TyG quartile HR: 1.36; TyG AUC: 0.578; HOMA-IR AUC: 0.543	Present study showed higher AUC because outcome was high biochemical risk, not long-term ASCVD event
Rafiee et al. [16]	2024	5432 Iranian adults; 11.2-year follow-up	TyG index for CVD	Incident CVD: 15.0%; highest TyG tertile HR: 1.48	Supports TyG as a CVD risk marker across non-East Asian populations
Zeng et al. [17]	2024	8531 middle-aged/older Chinese adults; CHARLS	Combined TyG and AIP	High TyG + high AIP group: OR 1.23 for CVD cross-sectionally;	Supports combined TyG–AIP approach; present study further

		national cohort; 9-year follow-up		HR 1.27 longitudinally	added SUA and achieved cluster AUC 0.91
Chen et al. [18]	2026	Middle-aged and older population; cohort study	Combined TyG, AIP and TyG-AIP	Higher TyG, AIP and TyG-AIP were associated with increased CVD, stroke and heart disease risk	Supports combined index concept; present study similarly found combined cluster stronger than individual markers
Lertsakulbunlue et al. [19]	2024	Royal Thai Army personnel	TyG index and hyperuricemia	Hyperuricemia prevalence: 31.4%; fourth TyG quartile AOR: 2.45 for hyperuricemia; SUA increased by 0.32 mg/dL per unit TyG rise	Present hyperuricemia was 38.0%; TyG correlated positively with SUA [r=0.46]
Wang et al. [20]	2025	Dose-response meta-analysis; 26 studies; 637,954 participants	TyG index and hyperuricemia	TyG associated with hyperuricemia: OR 2.67; each 1-unit TyG rise increased hyperuricemia risk 2.07 times	Strongly supports adding SUA to a TyG-based cardiometabolic risk cluster

The atherogenic index of plasma adds another dimension to cardiometabolic risk because it reflects the balance between triglyceride-rich lipoproteins and HDL cholesterol. In the present study, AIP increased from 0.05 ± 0.08 in the low-risk group to 0.25 ± 0.10 in the moderate-risk group and 0.55 ± 0.16 in the high-risk group [p<0.001]. Raised AIP was seen in 49.0% of participants. Triglycerides increased from 108.6 ± 22.4 mg/dL to 212.4 ± 44.8 mg/dL, while HDL cholesterol decreased from 49.6 ± 7.8 mg/dL to 37.4 ± 6.4 mg/dL across low- to high-risk groups. These changes indicate an atherogenic dyslipidemic pattern.

Recent evidence supports combined interpretation of TyG index and AIP. Zeng et al,[17] using CHARLS national cohort data, evaluated the joint effect of TyG index and AIP on cardiovascular disease. In cross-sectional analysis of 8531 participants, the high TyG and high AIP group had OR 1.23 for CVD compared with the low TyG and low AIP group. In longitudinal survival analysis over 9 years, TyG alone had HR 1.19, AIP alone had HR 1.25, and the combined high TyG–high AIP group had HR 1.27 for CVD. Chen et al,[18] also reported that higher TyG, AIP and TyG-AIP were associated with increased cardiovascular disease, stroke and heart disease risk among middle-aged and older adults. These findings support the present study, where the combined biochemical cluster showed better diagnostic performance than individual markers.

Serum uric acid was included in the present cluster because hyperuricemia is linked with insulin resistance, oxidative stress, endothelial dysfunction, hypertension and metabolic dysregulation. In this study, serum uric acid increased from 4.7 ± 0.8 mg/dL in the low-risk group to 7.1 ± 1.2 mg/dL in the high-risk group [p<0.001]. Hyperuricemia was present in 38.0% of participants, and TyG index showed significant positive correlation with serum uric acid [r=0.46, p<0.001]. Lertsakulbunlue et al,[19] in a 2024 study among Royal Thai Army personnel, reported that serum uric acid increased by 0.32 mg/dL for each unit increase in TyG index. They also reported that participants in the fourth TyG quartile had an adjusted odds ratio of 2.45 for hyperuricemia compared with the first quartile. This closely supports the positive TyG–SUA relationship observed in the present study.

Further support comes from the 2025 dose-response meta-analysis by Wang et al,[20] which found that TyG was associated with hyperuricemia, with OR 2.67. The same analysis also reported that each 1-unit increase in TyG index increased hyperuricemia risk 2.07 times. These findings justify adding serum uric acid to TyG and AIP rather than treating it as an isolated metabolic parameter. In the present study, all three markers were abnormal in 25.0% of participants and two or more abnormal cluster markers were seen in 57.0%, indicating that these abnormalities frequently coexist.

The combined SUA–TyG–AIP cluster performed better than individual markers in the present study. Serum uric acid alone had AUC 0.76, TyG index had AUC 0.84 and AIP had AUC 0.82, while the combined cluster showed AUC 0.91 with sensitivity 89.3% and specificity 83.3%. This pattern is biologically plausible because the three markers reflect complementary domains: serum uric acid reflects purine-related metabolic stress and oxidative-endothelial burden, TyG index reflects insulin resistance-related glucose-triglyceride dysregulation, and AIP reflects atherogenic dyslipidemia. Together, they may identify a broader early cardiometabolic risk phenotype than any single marker.

The present findings are particularly relevant in Indian adults, where diabetes, dyslipidemia, hypertension and premature cardiovascular disease often emerge at lower body mass index and younger age compared with many Western populations. A simple laboratory-derived cluster using fasting glucose, triglycerides, HDL cholesterol and serum uric acid can be calculated without additional expensive testing. This makes the SUA–TyG–AIP

cluster potentially useful in routine health screening, especially in resource-limited settings.

The study has some limitations. It was cross-sectional and therefore cannot establish causality or future disease prediction. The sample size was 100 and the study was conducted at a single institute. Anthropometric and clinical variables such as BMI, waist circumference, blood pressure, dietary habits, physical activity and family history were not included in the main analysis. Fasting insulin and HOMA-IR were not measured, so direct comparison with insulin-based indices was not possible. Longitudinal follow-up is required to determine whether this biochemical cluster predicts future diabetes, hypertension or cardiovascular events in Indian adults.

Overall, the present study supports the use of a low-cost biochemical cluster consisting of serum uric acid, TyG index and atherogenic index of plasma for early cardiometabolic risk identification. The findings are consistent with recent prospective studies and meta-analyses showing that TyG index is associated with metabolic syndrome, diabetes and cardiovascular disease, while recent studies also support the association of TyG with hyperuricemia and the combined value of TyG with AIP. Larger multicentric prospective Indian studies are recommended to validate the proposed SUA–TyG–AIP cluster and establish population-specific cut-off values.

CONCLUSION

The present study showed that serum uric acid, triglyceride-glucose index and atherogenic index of plasma are useful low-cost biochemical markers for identifying early cardiometabolic risk among Indian adults. In this study of 100 participants, moderate to high biochemical cardiometabolic risk was observed in 66.0% of participants. Raised TyG index was present in 54.0%, raised AIP in 49.0%, and hyperuricemia in 38.0% of participants.

Serum uric acid, TyG index and AIP increased progressively across low-, moderate- and high-risk groups. TyG index showed significant positive correlation with fasting plasma glucose, triglycerides, AIP and serum uric acid, indicating clustering of insulin resistance-related and atherogenic biochemical abnormalities.

The combined SUA–TyG–AIP cluster showed better performance than individual markers for identifying high biochemical cardiometabolic risk, with an AUC of 0.91. Therefore, this laboratory-derived cluster may serve as a simple, affordable and practical biochemical signature for early cardiometabolic risk screening in routine clinical biochemistry practice.

Limitations

The present study had certain limitations. It was a cross-sectional observational study; therefore, causal relationships and future prediction of diabetes, hypertension or cardiovascular disease could not be established. The study included 100 participants from a single institute, which may limit generalizability.

Clinical and anthropometric parameters such as body mass index, waist circumference, blood pressure, dietary pattern, physical activity, smoking status and family history were not included in the main analysis. Fasting insulin and HOMA-IR were not measured, so direct comparison with insulin-based insulin resistance indices was not possible.

The cardiometabolic risk classification was based on biochemical markers and not on long-term clinical cardiovascular outcomes. Hence, prospective follow-up studies are required to validate the predictive value of the SUA–TyG–AIP cluster.

Recommendations

Serum uric acid, TyG index and AIP may be incorporated into routine biochemical risk assessment where fasting glucose and lipid profile are already available. Since these markers are inexpensive and easily calculable, they may be useful in screening apparently non-diabetic adults for early biochemical cardiometabolic risk.

Future studies should include larger sample size, multicentric Indian populations and prospective follow-up to assess whether the SUA–TyG–AIP cluster predicts development of diabetes mellitus, hypertension, metabolic syndrome and cardiovascular events.

Further research should also include anthropometric parameters, blood pressure, lifestyle risk factors, fasting insulin, HOMA-IR and inflammatory markers to strengthen the clinical interpretation of this biochemical cluster.

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