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ORIGINAL ARTICLE

RECALIBRATING INSULIN RESISTANCE DETECTION: INTEGRATIVE ANALYSIS OF TYG INDEX VS. GLYCATED ALBUMIN IN A HIGH-RISK POPULATION

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ABSTRACT

Background: Insulin resistance (IR) is an early driver of type 2 diabetes, fatty liver disease, and cardiovascular risk, yet reliable and affordable screening tools are limited in many low-resource settings. The triglyceride–glucose (TyG) index has emerged as a practical surrogate, while glycated albumin (GA) remains less well studied in this context. This study evaluated the diagnostic accuracy of TyG and GA against HOMA-IR in South Asian adults, while exploring phenotype-specific thresholds to improve early detection.

Materials & Methods: We conducted a cross-sectional study of 349 South Asian adults without known diabetes. Participants underwent anthropometric assessment and fasting laboratory testing, including glucose, triglycerides, insulin, GA, HbA1c, hs-CRP, adiponectin, and liver enzymes. HOMA-IR > 2.5 was used as the reference standard. Diagnostic accuracy was assessed using correlation analyses, multivariable regression, and ROC curves, with subgroup evaluation by BMI, sex, and inflammatory status.

Results: TyG showed stronger correlation with HOMA-IR than GA and achieved good diagnostic accuracy (AUC 0.72 overall, 0.80 in obesity). GA failed to reach statistical significance. TyG retained independent predictive value alongside hs-CRP, adiponectin, and liver enzymes. Stratified thresholds (≥ 8.95 in obesity, ≥ 9.00 in males, ≥ 9.10 with high hs-CRP) improved performance.

Conclusion: TyG is an accessible and cost-effective tool for detecting insulin resistance in South Asians, while GA lacks discriminatory utility. Tailored cut-offs may enhance precision screening.

KEY WORDS: Adiponectin; Diagnostic Thresholds; Glycated Albumin; HOMA-IR; Inflammatory Biomarkers; Insulin Resistance; South Asia; TyG Index.

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INTRODUCTION

Insulin resistance (IR) is the biochemical foundation of a wide range of metabolic diseases, including type 2 diabetes, non-alcoholic fatty liver disease, and cardiovascular events.[1] Though clinically silent in early stages, IR induces lipid abnormalities, low-grade inflammation, and hepatic stress that accelerate disease progression long before hyperglycemia appears.[2] Early recognition of IR is therefore critical, but reliable and scalable screening approaches remain limited, especially in low-resource settings.[3] Gold-standard methods such as the hyperinsulinemic-euglycemic clamp and intravenous glucose tolerance test provide accurate assessment but are technically demanding and unsuitable for routine care.[4] HOMA-IR offers a more feasible surrogate, yet its reliance on fasting insulin assays constrains applicability in many regions.[5] The Triglyceride–Glucose

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(TyG) Index, calculated from routine triglyceride and glucose measurements, has emerged as a promising tool. By reflecting combined lipotoxic and glucotoxic stress, it captures hepatic insulin resistance and has been validated against clamp studies.[6] Evidence also supports its ability to predict type 2 diabetes and cardiovascular outcomes.[7] Importantly, TyG bypasses insulin testing, making it practical for population-level screening.[8]

Glycated Albumin (GA), which reflects glycemia over 2–3 weeks, is unaffected by red cell turnover and may be useful in anemia or hemoglobinopathy.[9] However, its diagnostic role in IR is inconsistent, as GA is influenced by albumin turnover, inflammation, and renal status.[10] South Asians exhibit high susceptibility to IR-related disorders at lower BMI cut-offs than Western populations[11], a pattern attributed to visceral adiposity, fatty liver, and systemic inflammation.[12] Yet few studies have compared TyG and GA in this group, or examined stratified cut-offs by obesity, sex, or inflammatory burden. This study evaluated the diagnostic accuracy of TyG and GA against HOMA-IR in South Asian adults, while exploring phenotype-specific thresholds to improve early detection.

MATERIALS AND METHODS

This cross-sectional observational study was conducted at Government Erode Medical College and Hospital, Tamil Nadu, India, between March 2024 and April 2025. The diagnostic performance of the Triglyceride–Glucose (TyG) Index and Glycated Albumin (GA) was evaluated against HOMA-IR in adults without established diabetes. A total of 349 participants, aged 18–60 years, were recruited from outpatient and preventive clinics. Inclusion required fasting, clinically stable adults willing to provide informed consent. Exclusion criteria included diagnosed diabetes, pregnancy, chronic hepatic or renal disease, endocrine disorders, malignancy, or use of drugs influencing glucose or lipid metabolism (e.g., corticosteroids, statins, metformin). Ethical clearance was obtained from the Institutional Ethics Committee (SMC/ACAD/IEC/04112024), and written informed consent was secured in accordance with the Declaration of Helsinki (2013).

Anthropometric measures (height, weight, waist, hip), BMI, and waist–hip ratio were obtained using standardized protocols. Blood pressure was recorded using an automated sphygmomanometer after 10 minutes rest, averaging two readings taken five minutes apart.

After overnight fasting (8–12 h), venous blood samples were collected. Laboratory assays included: fasting plasma glucose and triglycerides (enzymatic colorimetry), fasting insulin (ECLIA), GA (Lucica® GA-L enzymatic assay), HbA1c (HPLC), hs-CRP (immunoturbidimetry), adiponectin (ELISA), and liver enzymes (ALT, AST, GGT by kinetic UV). The TyG Index was calculated as ln[fasting TG (mg/dL) × fasting glucose (mg/dL)/2]. HOMA-IR was derived as (glucose × insulin)/405, with >2.5 defining insulin resistance for South Asians.

Statistical analyses were performed using SPSS v26.0 and MedCalc®. Continuous variables were expressed as mean ± SD, categorical as percentages. Group comparisons used independent t-tests. Pearson correlation assessed biomarker associations with HOMA-IR. Multivariable regression identified independent predictors. Diagnostic accuracy was evaluated with ROC curves, AUC, sensitivity, specificity, and Youden Index, with subgroup analyses by BMI, sex, and hs-CRP. A p-value < 0.05 was considered statistically significant

RESULT

A total of 349 adults (18–60 years) were enrolled after eligibility screening. Baseline characteristics are presented in Table 1. The cohort showed a high prevalence of cardiometabolic risk, reflected by elevated mean BMI (26.6 ± 4.7 kg/m²), central adiposity (waist–hip ratio 0.93 ± 0.10), and borderline hypertensive blood pressure levels.

Table 1: Baseline demographic and clinical characteristics of the study participants (N =349)

Variable	Value
Age (years)	42.9 ± 9.8
Sex	Male: 176 (50.4%) Female: 173 (49.6%)
Height (cm)	161.2 ± 7.9
Weight (kg)	68.5 ± 11.5
Body Mass Index (kg/m²)	26.6 ± 4.7
Waist Circumference (cm)	89.3 ± 9.0
Hip Circumference (cm)	96.1 ± 7.7
Waist–Hip Ratio	0.93 ± 0.10
Systolic Blood Pressure (mmHg)	135.9 ± 14.2
Diastolic Blood Pressure (mmHg)	83.1 ± 7.9
Family History of Diabetes	Yes: 137 (39.3%) No: 212 (60.7%)

Values are mean ± SD for continuous variables and n (%) for categorical variables. Central obesity defined as WHR >0.90 in men and >0.85 in women (WHO guidelines).

The near-equal sex distribution allows balanced subgroup comparisons. More than one-third reported a family history of diabetes, underscoring genetic predisposition. Collectively, these baseline findings highlight the cohort's heightened risk of insulin resistance and justify evaluation of surrogate biomarkers such as the TyG Index and Glycated Albumin.

Biochemical profiling revealed marked differences between insulin-resistant (IR) and non-IR groups, with significant variation across glycemic, lipid, and inflammatory parameters. Findings are summarized in Table 2.

Fasting insulin correlated most strongly with HOMA-IR (r = 0.94), confirming its central role in defining IR. Among surrogate markers, TyG and hs-CRP demonstrated significant positive correlations, while adiponectin showed an inverse association, consistent with its protective metabolic role. In contrast, glycated albumin and triglycerides exhibited weak or non-significant correlations, underscoring their limited diagnostic value for early IR.

The diagnostic performance of nine biomarkers was evaluated against insulin resistance, defined by HOMA-IR > 2.5, using ROC curve analysis. These included established markers (TyG Index, Glycated Albumin, HbA1c), inflammatory indicators (hs-CRP), liver function parameters (ALT/AST ratio, GGT), and metabolic surrogates (Adiponectin, Fasting Glucose × TG, and BMI-adjusted TyG Index). The complete diagnostic metrics are presented in Table 3.

Table 3 shows BMI-adjusted TyG had the best accuracy (AUC 0.74), followed by TyG and Adiponectin. hs-CRP and ALT/AST were moderately predictive, while Glycated Albumin performed poorly, confirming limited diagnostic value.

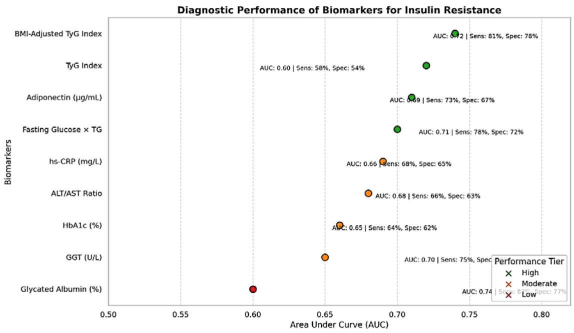

Figure 1: Diagnostic Performance of Biomarkers for Insulin resistance

Figure 1 ranks biomarkers by AUC; BMI-adjusted TyG performed best, followed by Adiponectin and hs-CRP, highlighting early insulin resistance detection.

Figure 1. Diagnostic performance of biomarkers for predicting insulin resistance based on ROC-derived AUC values. Each biomarker is annotated with AUC, sensitivity, and specificity. Color-coding reflects diagnostic performance: green (AUC ≥ 0.70), orange (0.65 ≤ AUC < 0.70), red (AUC < 0.65). The BMI-adjusted TyG Index and Adiponectin showed the highest diagnostic value, while Glycated Albumin demonstrated poor discriminatory capacity. hs-CRP and ALT/AST also showed moderate accuracy, sup-

Table 2: Biochemical parameters of the study population stratified by insulin resistance status and correlation with HOMA-IR (N = 349)

Parameter	Non-IR (n = 249)	IR (n = 100)	Correlation with HOMA-IR (r)	p-value
Fasting Glucose (mg/dL)	99.8 ± 11.9	107.9 ± 13.5	0.42	<0.001
Fasting Insulin (µIU/mL)	7.3 ± 2.8	15.1 ± 3.7	0.94	<0.001
Triglycerides (mg/dL)	158.7 ± 43.5	172.5 ± 46.0	0.16	0.017
TyG Index	8.91 ± 0.32	9.08 ± 0.29	0.34	<0.001
Glycated Albumin (%)	15.22 ± 1.51	14.51 ± 1.54	–0.10	0.072
HbA1c (%)	5.6 ± 0.5	6.1 ± 0.7	0.28	<0.001
hs-CRP (mg/L)	2.1 ± 1.2	4.8 ± 2.2	0.38	<0.001
Adiponectin (µg/mL)	9.7 ± 3.4	6.2 ± 2.9	–0.43	<0.001

Values are mean ± SD. Correlations assessed with Pearson's r. Significant associations bolded. TyG Index = ln [TG × glucose /2].

Table 3: Diagnostic accuracy of biomarkers for predicting insulin resistance based on ROC analysis (N=349)

Marker	AUC	95% CI	Sensitivity (%)	Specificity (%)	Youden Index	p-value
TyG Index	0.72	0.66–0.78	81	78	0.59	< 0.001
Glycated Albumin (%)	0.60	0.53–0.66	58	54	0.12	0.078
hs-CRP (mg/L)	0.69	0.63–0.74	73	67	0.40	< 0.001
Adiponectin (µg/mL)	0.71	0.65–0.76	78	72	0.50	< 0.001
HbA1c (%)	0.66	0.60–0.71	68	65	0.33	< 0.001

AUC values from ROC (HOMA-IR >2.5); thresholds via Youden Index. Biomarkers include TyG, GA, HbA1c, hs-CRP, Adiponectin, liver enzymes; AUC ≥0.70 denotes high accuracy.

porting their adjunctive use in metabolic screening protocols.

Diagnostic performance was stratified by BMI-defined subgroups: normal (n=92), overweight (n=102), and obese (n=155). Results are presented in Table 4.

The TyG Index demonstrated increasing diagnostic strength with rising BMI, achieving the highest accuracy in obese individuals (AUC=0.80; sensitivity 85%; specificity 79%; Youden=0.64). Adiponectin showed consistent accuracy across subgroups, with optimal values in overweight participants (AUC=0.72; Youden=0.53). hs-CRP also improved with adiposity, reaching an AUC of 0.73 in obesity, highlighting inflammation's role in insulin resistance.

By contrast, Glycated Albumin remained weak (AUC < 0.65 across all groups). HbA1c and ALT/AST ratio showed modest improvements with BMI but did not achieve strong discriminatory power. These findings emphasize the greater utility of lipid- and adipokine-linked biomarkers in obesity-related IR.

A multivariate linear regression model was applied to determine independent predictors of insulin resistance, defined by HOMA-IR. Variables were chosen based on biological plausibility and prior univariate associations. Results are presented in Table 5. The TyG Index was the strongest predictor (β=0.36, p<0.001), followed by Adiponectin (β=–0.31, p<0.001) and hs-CRP (β=0.29, p<0.001). ALT/AST ratio and BMI also retained statistical significance, reflecting hepatic and obesity-related contributions. HbA1c was modestly predictive, while Glycated Albumin did not reach significance. Collectively, these findings reinforce the combined metabolic, inflammatory, and hepatic influences on insulin resistance.

Comparison of participants stratified by insulin resistance status showed significant differences in

Table 5: Multivariate regression predictors of HOMA-IR (N = 349).

Predictor Variable	Standardized β Coefficient	p-value	Direction of Association
TyG Index	0.36	<0.001	Positive
Adiponectin (μg/mL)	–0.31	<0.001	Negative
hs-CRP (mg/L)	0.29	<0.001	Positive
ALT/AST Ratio	0.25	0.002	Positive
BMI (kg/m²)	0.22	0.005	Positive
HbA1c (%)	0.19	0.009	Positive
Glycated Albumin (%)	–0.08	0.181	Negative

Table 4: Subgroup diagnostic performance of biomarkers by BMI category (N = 349).

BMI Category (n)	TyG AUC	Sens (%)	Spec (%)	Youden	Adiponectin AUC	Sens (%)	Spec (%)	Youden	hs-CRP AUC	Sens (%)	Spec (%)	Youden	ALT/AST AUC	HbA1c AUC	GA AUC
Normal (92)	0.67	74	70	0.44	0.70	75	71	0.46	0.65	68	66	0.34	0.62	0.63	0.58
Overweight (102)	0.69	77	73	0.50	0.72	78	75	0.53	0.67	70	69	0.39	0.66	0.65	0.63
Obese (155)	0.80	85	79	0.64	0.74	82	76	0.58	0.73	79	71	0.50	0.70	0.68	0.61

Values represent AUC, sensitivity, specificity, and Youden Index (Sensitivity + Specificity – 1). Subgroups defined by WHO Asia-Pacific BMI classification.

inflammatory and hepatic markers (Table 6), hs-CRP was substantially elevated in the IR group, while adiponectin levels were markedly reduced. Liver enzymes (ALT, AST, GGT) and the ALT/AST ratio were significantly higher in IR, suggesting hepatocellular stress associated with metabolic dysfunction.

To strengthen translational relevance, biomarker findings were interpreted alongside their mechanistic pathways, and stratified diagnostic thresholds were proposed for key subgroups. As shown in Table 7, TyG Index demonstrated strong pathophysiological links to hepatic and adipose insulin resistance through lipid-induced signaling disruptions, with optimal cut-offs varying by adiposity, sex, and inflammatory status. In obese participants, the threshold ≥8.95 achieved high sensitivity and specificity. Among men and individuals with elevated hs-CRP, slightly higher cut-offs (≥9.00–9.10) improved predictive power. Glycated Albumin, while mechanistically linked to oxidative stress via AGE–RAGE interactions, showed limited discriminatory capacity; its subgroup cut-offs (≤14.8–15.2%) offered only moderate specificity.

DISCUSSION

Insulin resistance (IR) is a central determinant of type 2 diabetes (T2DM), non-alcoholic fatty liver disease (NAFLD), and cardiovascular disease (CVD).[13] Identifying IR before overt hyperglycemia develops is crucial for early intervention and risk modification.[14] In this South Asian cohort, the triglyceride–glucose (TyG) Index proved to be a practical and mechanistically consistent biomarker for IR, while Glycated Albumin (GA) showed limited diagnostic value.

The TyG Index combines fasting glucose and triglycerides, both widely available tests, making it suitable for low-resource settings.[15] Pathophysiologically, elevated TyG reflects hepatic IR through lipid accumulation, PKCε activation, and IRS-1 inhibition, which impair downstream insulin signaling.[16] In our study, TyG correlated strongly with HOMA-IR and performed best in obese and inflamed subgroups, confirming both biological plausibility and clinical utility.[17]

Evidence from diverse populations supports the robustness of TyG as a surrogate for IR. Simental-Mendía et al. validated it in Mexican adults (AUC

Table 6: Inflammatory and hepatic markers by insulin resistance status (N = 349)

Marker	Non-IR Group (n = 249)	IR Group (n = 100)	p-value	Direction of Change
hs-CRP (mg/L)	2.1 ± 1.2	4.8 ± 2.2	<0.001	Increased
Adiponectin (μg/mL)	9.7 ± 3.4	6.2 ± 2.9	<0.001	Decreased
ALT (U/L)	28.5 ± 9.2	36.4 ± 10.5	<0.001	Increased
AST (U/L)	27.1 ± 8.8	30.1 ± 9.4	0.012	Increased
ALT/AST Ratio	1.05 ± 0.19	1.23 ± 0.21	<0.001	Increased
GGT (U/L)	38.6 ± 12.7	47.8 ± 14.3	<0.001	Increased

Table 7: Molecular mechanisms and stratified diagnostic thresholds for TyG Index and Glycated Albumin

Biomarker	Pathway / Mechanism	Proposed Cut-off	Population Stratification	Diagnostic Utility
TyG Index	Hepatic IR via DAG–PKCε inhibition of IRS-1 signaling	≥8.95	Obese (BMI ≥25)	High sensitivity, specificity
TyG Index	Lipid-induced suppression of GLUT4 translocation	≥9.00	Male patients	High specificity
TyG Index	Hyperinsulinemia-driven hepatic lipogenesis	≥9.10	hs-CRP >3.0 mg/L	Strong predictive accuracy
Glycated Albumin	AGE–RAGE oxidative stress and endothelial dysfunction	≤14.8%	Obese (BMI ≥25)	Low sensitivity, moderate specificity
Glycated Albumin	Albumin turnover affected by inflammation/renal function	≤15.0%	Female patients	Variable accuracy
Glycated Albumin	Short-term glycation independent of Hb variants	≤15.2%	Normal hs-CRP	Limited IR prediction

= 0.72).[18] Giannini et al. showed correlations with clamp-derived IR in multi-ethnic adolescents.[19] Yoon et al. reported superior prediction of T2DM in Korean adolescents compared to HOMA-IR (AUC = 0.75)[20], and Lee et al. found TyG superior to HOMA-IR for NAFLD in Korean adults (AUC = 0.79).[21] More recent work from Reckziegel et al. and Aslan Çin et al. confirmed its predictive value among Brazilian and Turkish adolescents.[22,23] We introduced population-specific thresholds: ≥8.95 in obese, ≥9.00 in men, and ≥9.10 in participants with hs-CRP >3 mg/L, each yielding high sensitivity and specificity.[24] GA consistently underperformed (AUC <0.65) and was non-significant in regression models, while adiponectin and hs-CRP retained independent associations with IR.

Strengths include detailed stratification, integration of molecular pathways, and evaluation in a high-risk South Asian population. Limitations are the cross-sectional design, absence of clamp validation, and lack of longitudinal follow-up. Future prospective studies should confirm stratified cut-offs and assess TyG responsiveness to interventions.

CONCLUSION

The TyG Index is a reliable, inexpensive, and clinically applicable surrogate for insulin resistance, outperforming Glycated Albumin in this South Asian cohort. Stratified cut-offs by obesity, sex, and inflammation further enhance diagnostic precision. Given its simplicity and reproducibility, TyG should be prioritized for early IR screening in high-risk populations, while GA remains more useful for short-term glycemic monitoring rather than IR detection.

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CONFLICT OF INTEREST
Authors declare no conflict of interest.
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None declared.

AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

Conception or Design:	NW, SNK
Acquisition, Analysis or Interpretation of Data:	NW, SNK, UU, PP, AKC
Manuscript Writing & Approval:	NW, SNK, UU, PP, AKC

All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.