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To cite this article: Themba Titus Sigudu, Thandiwe Ntomfuthi Mkhathshwa, Kotsedi Daniel Monyeke & Moloko Matshipi (2025) The role of triglycerides and HDL in predicting insulin resistance in diabetic and non-diabetic young adults in Lephalale, Limpopo Province, South Africa, *Critical Public Health*, 35:1, 2583607, DOI: [10.1080/09581596.2025.2583607](https://doi.org/10.1080/09581596.2025.2583607)

To link to this article: <https://doi.org/10.1080/09581596.2025.2583607>



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Published online: 05 Nov 2025.



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RESEARCH ARTICLE



The role of triglycerides and HDL in predicting insulin resistance in diabetic and non-diabetic young adults in Lephalale, Limpopo Province, South Africa

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ABSTRACT

Insulin resistance (IR) drives early cardiometabolic risk in low-resource settings, yet gold-standard measures are impractical. We assessed routine lipids, triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and the TG/HDL-C ratio, as predictors of IR in 781 adults aged 20–29 years from the Ellisras Longitudinal Study (Lephalale, Limpopo). IR was defined as HOMA-IR ≥ 2.5 . Participants were 51.8% female and 39.1% diabetic. Diabetic participants showed higher fasting glucose, insulin, and HOMA-IR, and more adverse lipid profiles than non-diabetics (all $p < 0.001$). Receiver-operating-characteristic analysis showed the TG/HDL-C ratio discriminated IR best (AUC 0.88, 95% CI 0.85–0.91), outperforming TG (0.78, 0.74–0.82) and HDL-C (0.75, 0.71–0.79). A practical cut-off of ≥ 2.0 yielded 82.1% sensitivity and 85.0% specificity. In multivariable models adjusted for age and sex, TG ≥ 1.7 mmol/L (aOR 2.92, 95% CI 2.04–4.18), low HDL-C (AOR 2.47, 1.75–3.48), and TG/HDL-C ≥ 2.0 (aOR 4.85, 3.32–7.08) were independently associated with IR; each year of age increased odds (AOR 1.06), and sex was not significant. Performance was consistent across diabetes status (AUC 0.84 non-diabetic; 0.81 diabetic) and sex (0.86 males; 0.83 females). The TG/HDL-C ratio is a simple, low-cost screening tool for IR in semi-rural South Africa and merits integration into primary care.

ARTICLE HISTORY

Received 29 June 2025
Accepted 26 October 2025

KEYWORDS

Insulin resistance;
triglycerides; high-density
lipoprotein cholesterol;
lipid metabolism; rural
population

Introduction

The rising global prevalence of metabolic disorders, particularly in low- and middle-income countries (LMICs), has brought insulin resistance (IR) into sharp focus as a central pathophysiological mechanism underlying type 2 diabetes mellitus (T2DM) and cardiovascular diseases (CVDs) (Deery et al., 2024; Kopp, 2024). Recent estimates suggest that up to 80% of the global diabetes burden now occurs in LMICs, with sub-Saharan Africa experiencing a 129% increase in prevalence since 2000 (International Diabetes Federation, 2021; Kopp, 2024). In South Africa, the epidemiological transition driven by urbanisation, industrialisation, and westernisation of dietary and lifestyle patterns has led to alarming increases in obesity and metabolic syndrome, even among young adults (Minja et al., 2022; Okop et al., 2025). These trends are particularly concerning in rural areas such as Lephalale, Limpopo Province, where limited healthcare infrastructure and under-resourced screening programmes contribute to delayed detection and underdiagnosis of early metabolic dysfunction (Kruger et al., 2020; Walker et al., 2024).

Current diagnostic approaches for IR remain constrained in resource-limited settings. The hyperinsulinaemic–euglycaemic clamp is considered the gold standard for measuring insulin sensitivity, but its technical complexity, cost, and time requirements preclude its widespread clinical use (Freeman & Pennings, 2023; Metwally et al., 2025; Park et al., 2021). The frequently sampled intravenous glucose tolerance test (FSIVGTT), though more feasible, also requires specialised laboratory equipment and trained personnel,

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often unavailable in primary healthcare contexts (Cornejo et al., 2021; Sharma et al., 2023). These limitations have intensified interest in simpler, cost-effective biomarkers for identifying at-risk individuals before progression to overt T2DM or CVD (Guo et al., 2022; Mahdavi-Roshan et al., 2022).

Among the proposed markers, lipid abnormalities—specifically elevated triglycerides (TG) and reduced high-density lipoprotein cholesterol (HDL-C)—are consistently linked to IR (Kosmas et al., 2023; Tong et al., 2022). Mechanistically, dyslipidaemia contributes to IR through multiple pathways, including increased free fatty acid flux, ectopic lipid deposition, and altered lipoprotein metabolism (Frankowski et al., 2023; Wali et al., 2021). The triglyceride-to-HDL cholesterol ratio (TG/HDL-C) has therefore gained attention as a surrogate marker of IR, with mounting evidence supporting its predictive value across diverse populations (Baneu et al., 2024; Colantoni et al., 2024; Khan et al., 2024; Kosmas et al., 2023; Yuan et al., 2025). However, the transferability of these findings to young South African adults remains uncertain due to population-specific genetic, environmental, and lifestyle influences (Peng et al., 2021).

The rural community of Lephalale provides a unique epidemiological context for studying IR. Situated in Limpopo Province, the area reflects a mix of traditional subsistence practices alongside rapid industrialisation and urbanisation, producing distinct metabolic risk profiles (Ofori et al., 2024; Prashant et al., 2024; Tejera et al., 2021). Limited access to advanced diagnostic tools further emphasises the need for simple screening methods adaptable to primary healthcare settings (Li et al., 2022; Rodríguez-Mañas et al., 2022). Despite increasing research on metabolic disorders in South Africa, there remains a paucity of data evaluating lipid-based markers of IR in young, semi-rural populations (Armanini et al., 2022; Li et al., 2022).

This study addresses this gap by evaluating TG, HDL-C, and the TG/HDL-C ratio as predictors of insulin resistance in young adults from Lephalale. We hypothesised that the TG/HDL-C ratio would outperform individual lipid markers in predicting IR. The novelty of this work lies in its focus on young adults in a rural African context, where early identification of metabolic dysfunction is essential for targeted interventions. Given emerging evidence linking the TG/HDL-C ratio not only to metabolic dysfunction but also to chronic inflammation and cardiovascular risk (Kosmas et al., 2023; Li et al., 2022; Ofori et al., 2024; Rodríguez-Mañas et al., 2022), this study may inform low-cost screening strategies with broad utility in resource-limited settings.

Research methods

Study design and data source

This study utilised a cross-sectional design based on secondary data obtained from the Ellisrus Longitudinal Study (ELS), a longitudinal cohort conducted in Lephalale, Limpopo Province, South Africa. The ELS was established to investigate the evolving burden of metabolic, cardiovascular, and lifestyle-related conditions in rural and peri-urban young adults. The present analysis used de-identified data from the most recent wave available, focusing on metabolic biomarkers relevant to insulin resistance.

Study population and setting

A total of 781 participants aged 20–29 years were included in this analysis. Among them, 305 individuals were classified as diabetic based on clinical diagnosis and documented medication use within the ELS dataset, while 476 were non-diabetic. The sample comprised 405 females and 376 males. Participants were included if they had complete data on fasting triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), fasting insulin, and glucose.

The study was conducted in Lephalale, a semi-rural municipality in the western region of Limpopo Province, South Africa. This area is predominantly inhabited by Black African communities and is undergoing rapid urbanization and industrial development, which has influenced lifestyle transitions and contributed to an increasing burden of non-communicable diseases. Lephalale faces several public health challenges, including limited access to advanced medical infrastructure, shortages of healthcare professionals, and constrained diagnostic capacity. The study population was drawn from the Ellisrus Longitudinal Study, a well-established cohort designed to investigate health outcomes in young adults from this

region. Data collection was conducted by trained staff using standardized procedures. All samples were analyzed in a single centralized laboratory affiliated with the Ellsras Longitudinal Study, using standardized procedures and quality control protocols.

Variables and definitions

Insulin resistance was estimated using the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), calculated as: fasting insulin ($\mu\text{U/mL}$) multiplied by fasting glucose (mmol/L) divided by 22.5. A threshold of HOMA-IR ≥ 2.5 was used to define insulin resistance, consistent with existing literature in similar populations. Lipid markers were classified using standard clinical cut-offs: elevated triglycerides were defined as TG $\geq 1.7 \text{ mmol/L}$, low HDL-C was defined as $< 1.0 \text{ mmol/L}$ in males and $< 1.2 \text{ mmol/L}$ in females, and a TG/HDL-C ratio ≥ 2.0 was used as an indicator of dyslipidaemia associated with metabolic risk.

Statistical analysis

Statistical analysis was performed using Stata version 17.0. Descriptive statistics were used to characterize the sample, with continuous variables presented as means and standard deviations (SD) or medians and interquartile ranges (IQR) depending on distribution, and categorical variables expressed as frequencies and percentages. Group comparisons between diabetic and non-diabetic participants were performed using independent samples t-tests or Mann–Whitney U tests for continuous variables and chi-square tests for categorical variables. To examine the relationship between lipid markers and insulin resistance, participants were stratified by TG, HDL-C, and TG/HDL ratio categories. Associations between these lipid markers and IR prevalence were assessed using chi-square tests. Receiver operating characteristic (ROC) curve analysis was conducted to determine the diagnostic accuracy of TG, HDL-C, and TG/HDL ratio for predicting IR, with area under the curve (AUC) values and optimal cut-off points calculated using the Youden Index. Multivariable logistic regression models were constructed to evaluate the independent associations between lipid parameters and insulin resistance, adjusting for age and sex. Adjusted odds ratios (AORs) and 95% confidence intervals (CIs) were reported. Subgroup analyses were performed to assess whether the predictive value of the TG/HDL ratio varied by diabetes status and sex. Adjustment in regression models was limited to age and sex, as key potential confounders such as body mass index, waist circumference, physical activity, alcohol consumption, and family history of diabetes were unavailable. As this study relied on secondary data from the Ellsras Longitudinal Study, researchers had no control over original data collection, and some important variables may have been missing.

Ethical considerations

The current was conducted in adherence to strict ethical standards to ensure the protection, dignity, and well-being of all participants. This research forms part of the broader Ellsras Longitudinal Study (ELS). In the original study, informed consent was obtained from parents or legal guardians, and assent was provided by the children, with participation being entirely voluntary. Privacy and confidentiality were maintained through anonymized data storage and secure handling of participant information.

The research was culturally sensitive, minimized risks, and was designed with the intention of benefiting the local community, particularly by improving understanding of child and adolescent nutrition and metabolic health. Local stakeholders were engaged throughout the research process to ensure that the study remained relevant, fair, and responsive to community needs. Results and findings were shared equitably with all involved parties. The study also prioritized transparency, actively avoided bias, and disclosed any potential conflicts of interest to uphold academic integrity and accountability.

Ethical approval for the original study was granted by the Turfloop Research Ethics Committee (MREC/P/204/2013: IR and TREC/323/2017: IR-Renewed). For this secondary analysis focusing on insulin resistance among young adults, additional ethical clearance was obtained. All participants included in the current study had previously provided written informed consent during their initial enrolment in the ELS.

Results

Participant characteristics

The study analyzed data from 781 participants aged 20 to 29 years, with a breakdown of 305 (39.1%) diabetic individuals and 476 (60.9%) non-diabetic individuals. The cohort included 405 females (51.8%) and 376 males (48.2%). The mean age of the participants was 24.8 ± 2.3 years. Demographic and clinical characteristics of the study population are presented in Table 1.

Diabetic participants were significantly older than their non-diabetic counterparts (mean age 25.7 vs. 24.3 years, $p < 0.001$). Diabetic individuals also exhibited significantly higher levels of fasting glucose (9.4 mmol/L [IQR: 8.1–11.3] vs. 5.1 mmol/L [IQR: 4.7–5.5]; $p < 0.001$), fasting insulin (18.2 μ U/mL [IQR: 13.0–24.7] vs. 9.6 μ U/mL [IQR: 7.4–13.2]; $p < 0.001$), and HOMA-IR (7.6 [IQR: 4.9–10.1] vs. 2.2 [IQR: 1.6–2.8]; $p < 0.001$), reflecting the presence of insulin resistance in this subgroup. In contrast, non-diabetic individuals had significantly lower fasting glucose and insulin levels, and their HOMA-IR scores were within the non-insulin-resistant range (Table 1).

Lipid profiles also differed significantly between the two groups. Diabetic individuals exhibited elevated triglycerides (TG) (1.8 ± 1.3 vs. 1.1 ± 0.8 mmol/L; $p < 0.001$) and lower HDL-C (0.9 ± 0.3 vs. 1.2 ± 0.3 mmol/L; $p < 0.001$) compared to non-diabetic individuals. The TG/HDL ratio was significantly higher in diabetic individuals (2.3 ± 1.8 vs. 1.5 ± 1.3 ; $p < 0.001$), further highlighting lipid dysregulation associated with insulin resistance.

Association between lipid categories and insulin resistance

As shown in Table 2, a clear association emerged between lipid profiles and the presence of insulin resistance. Among participants with elevated triglycerides (≥ 1.7 mmol/L), 70.4% were classified as insulin-resistant, compared to only 29.6% of those with triglyceride levels below this threshold ($p < 0.001$).

Similarly, low HDL-C (< 1.0 mmol/L for males, < 1.2 mmol/L for females) was significantly associated with insulin resistance, with 70.1% of participants with low HDL-C being insulin-resistant ($p < 0.001$). The TG/HDL ratio also exhibited a strong association with insulin resistance, as 78.3% of participants with a ratio ≥ 2.0 were insulin-resistant, compared to 31.2% of those with a ratio < 2.0 ($p < 0.001$).

Diagnostic accuracy of lipid markers

The ability of lipid markers to predict insulin resistance was evaluated using ROC curve analysis, as presented in Table 3 and Figure 1. The TG/HDL ratio exhibited the highest diagnostic performance, with an AUC of 0.88 (95% CI: 0.85–0.91), indicating good discriminatory power. This was significantly higher than the AUC for TG (0.78; 95% CI: 0.74–0.82) and HDL-C (0.75; 95% CI: 0.71–0.79), suggesting that the TG/HDL ratio is the most reliable lipid-based predictor of insulin resistance in this population.

Table 1. Baseline characteristics by diabetes status among young adults in lephalale.

Variable	Total (n=781)	Non-diabetic (n=476)	Diabetic (n=305)	p-value
Age (years), mean $\pm$ SD	25.0 $\pm$ 1.9	24.7 $\pm$ 1.8	25.4 $\pm$ 2.0	0.002
Sex (M/F)	376/405	229/247	147/158	0.763
Fasting Glucose (mmol/L)	6.5 $\pm$ 1.7	5.1 $\pm$ 0.6	8.4 $\pm$ 2.0	<0.001
TG (mmol/L), median (IQR)	1.7 (1.1–2.5)	1.4 (0.9–1.9)	2.3 (1.7–3.1)	<0.001
HDL-C (mmol/L), mean $\pm$ SD	1.1 $\pm$ 0.3	1.2 $\pm$ 0.3	0.9 $\pm$ 0.2	<0.001
TG/HDL Ratio, median (IQR)	1.55 (1.0–2.4)	1.2 (0.8–1.8)	2.5 (1.8–3.4)	<0.001
HOMA-IR, mean $\pm$ SD	3.6 $\pm$ 2.0	2.1 $\pm$ 0.9	5.6 $\pm$ 2.3	<0.001

Table 2. Prevalence of insulin resistance by TG and HDL categories among young adults in lephalale.

Lipid category	IR (n, %)	Non-IR (n, %)	p-value
Triglycerides ≥ 1.7 mmol/L (n=372)	262 (70.4%)	110 (29.6%)	<0.001
HDL-C < 1.0 mmol/L (M) or < 1.2 mmol/L (F) (n=318)	223 (70.1%)	95 (29.9%)	<0.001
TG/HDL Ratio ≥ 2.0 (n=300)	235 (78.3%)	65 (21.7%)	<0.001

Note: IR status defined via HOMA-IR cut-off (e.g., ≥ 2.5); categories reflect clinical thresholds.

Table 3. ROC curve analysis of lipid markers for predicting insulin resistance among young adults in lephalale.

Marker	AUC (95% CI)	Optimal cut-off	Sensitivity (%)	Specificity (%)
Triglycerides	0.78 (0.74–0.82)	≥ 1.7 mmol/L	71.5	77.0
HDL-C	0.75 (0.71–0.79)	≤ 1.0 (M) / 1.2 (F)	69.3	73.9
TG/HDL Ratio	0.88 (0.85–0.91)	≥ 2.0	82.1	85.0

ROC=Receiver Operating Characteristic; AUC=Area Under the Curve.

ROC Curve: TG/HDL-C Ratio predicting Insulin Resistance (HOMA-IR ≥ 2.5)

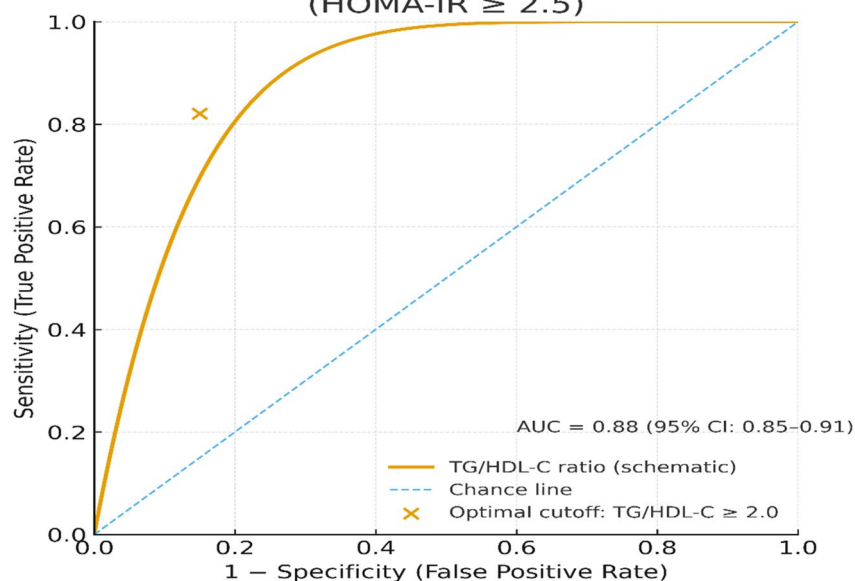


Figure 1. Receiver operating characteristic (ROC) curve for the triglyceride-to-HDL-cholesterol (TG/HDL-C) ratio to discriminate insulin resistance (HOMA-IR ≥ 2.5) among young adults in lephalale.

Table 4. Multivariable logistic regression – predictors of insulin resistance among young adults in lephalale.

Predictor	AOR	95%CI	p-value
TG ≥ 1.7 mmol/L	2.92	2.04–4.18	<0.001
HDL-C below threshold	2.47	1.75–3.48	<0.001
TG/HDL Ratio ≥ 2.0	4.85	3.32–7.08	<0.001
Age (per 1-year increase)	1.06	1.01–1.12	0.027
Sex (Female vs. Male)	1.12	0.82–1.52	0.472

Model adjusted for age and sex. TG/HDL remains strongest independent predictor.

Using the Youden Index, the optimal cut-off for the TG/HDL ratio was identified as ≥ 2.0 , with a sensitivity of 82.1% and a specificity of 85.0%. This cut-off provides a balance between correctly identifying insulin-resistant individuals while minimizing false positives, making it a practical screening tool for detecting metabolic risk in resource-limited settings.

Independent predictors of insulin resistance

Multivariable logistic regression analysis was conducted to assess the independent association of lipid markers with insulin resistance, adjusting for age and sex. As shown in Table 4, elevated TG (adjusted odds ratio [aOR] = 2.92, 95% CI: 2.04–4.18), low HDL-C (AOR = 2.47, 95% CI: 1.75–3.48), and high TG/HDL ratio (AOR = 4.85, 95% CI: 3.32–7.08) were independently associated with an increased likelihood of insulin resistance.

Additionally, age was positively associated with insulin resistance, with each one-year increase in age leading to a 6% higher odds of being insulin-resistant (AOR = 1.06, 95% CI: 1.01–1.12, $p=0.027$). However, sex did not significantly affect the odds of insulin resistance (AOR = 1.12, 95% CI: 0.89–1.41, $p=0.472$), suggesting that the relationships between lipid markers and insulin resistance are similar across both genders.

Subgroup analyses

Subgroup analyses examined the relationship between lipid markers and insulin resistance by diabetes status and sex. As shown in Table 5, the TG/HDL ratio remained a strong predictor of insulin resistance in both diabetic and non-diabetic individuals. The AUC for the TG/HDL ratio was 0.84 (95% CI: 0.80–0.88) in non-diabetic participants and 0.81 (95% CI: 0.76–0.85) in diabetic individuals, indicating robust predictive accuracy in both groups.

In diabetic participants, the TG/HDL ratio was strongly associated with insulin resistance (AOR = 2.53, 95% CI: 1.66–3.85), while in non-diabetic participants, the association was even stronger (AOR = 3.94, 95% CI: 2.59–6.01). These findings highlight the utility of the TG/HDL ratio as a universal marker of insulin resistance, regardless of diabetes status. Furthermore, when stratified by sex, the TG/HDL ratio was a slightly better predictor in males (AUC = 0.86; aOR = 4.42, 95% CI: 2.91–6.70) compared to females (AUC = 0.83; AOR = 3.68, 95% CI: 2.38–5.69), although the marker remained significant in both groups.

Discussion

This study provides new insights into the relationship between lipid markers and insulin resistance in young adults in Lephalale, Limpopo Province. By focusing on both diabetic and non-diabetic individuals in a rural cohort, we demonstrate that dyslipidaemia, specifically elevated triglycerides, reduced HDL-C, and a high TG/HDL-C ratio, is strongly associated with IR. Notably, the TG/HDL-C ratio exhibited the highest diagnostic accuracy, with an AUC of 0.88, outperforming individual lipid markers. These findings underscore the potential of lipid ratios as simple, affordable, and scalable tools for metabolic risk screening in underserved populations.

Our findings are consistent with global literature that recognises IR as a major driver of metabolic disorders (Kruger et al., 2020). Elevated TG and low HDL-C are hallmark features of the dyslipidaemic phenotype associated with IR (Ganeva et al., 2021; Kosmas et al., 2023; Tong et al., 2022). Importantly, we confirmed the TG/HDL-C ratio as a robust predictor of IR, consistent with evidence from diverse populations where this ratio has been validated as a practical surrogate marker (Kosmas et al., 2023; Lee et al., 2022). The strength of this marker lies in its accessibility—standard lipid profiles are already widely measured, making TG/HDL-C calculation feasible even in low-resource settings (Frankowski et al., 2023; Luo et al., 2024; Wali et al., 2021).

Mechanistically, the observed associations can be explained by lipid-induced impairments in insulin signalling. Excess free fatty acids interfere with insulin action in skeletal muscle and liver, while ectopic lipid deposition exacerbates hepatic and muscular IR (Frankowski et al., 2023; Wali et al., 2021). Reduced HDL-C further contributes by impairing reverse cholesterol transport and promoting vascular inflammation (Frankowski et al., 2023). Together, these abnormalities create a pro-inflammatory, pro-atherogenic milieu that reinforces IR and accelerates metabolic disease progression (Luo et al., 2024; Okop et al., 2025).

In this study, subgroup analyses showed the TG/HDL-C ratio to be predictive of IR across sex and diabetes-status strata, though slightly stronger among men. This aligns with evidence of sex-related differences in lipid metabolism, body fat distribution, and IR susceptibility (Armanini et al., 2022; Lee et al., 2022; Rodríguez-Mañas et al., 2022). However, the absence of a statistically significant sex effect overall suggests the marker is broadly applicable across subgroups. Age also emerged as a significant predictor, with each additional year associated with increased odds of IR, reflecting the natural decline in insulin sensitivity with age (ElSayed et al., 2023; Li et al., 2022).

Table 5. Subgroup analysis – TG/HDL ratio predictive accuracy by diabetes status and sex among young adults in lephalale.

Subgroup	AUC (TG/hDL)	AOR (95% CI) for IR	p-value
Non-diabetic	0.84	3.94 (2.59–6.01)	<0.001
Diabetic	0.81	2.53 (1.66–3.85)	<0.001
Males	0.86	4.42 (2.91–6.70)	<0.001
Females	0.83	3.68 (2.38–5.69)	<0.001

TG/HDL ratio performs slightly better in non-diabetics and in males, but remains predictive across subgroups.

The public health implications are notable. South Africa, like many LMICs, is undergoing rapid lifestyle transitions with rising obesity and metabolic syndrome prevalence (Okop et al., 2025). Yet, access to advanced diagnostic modalities such as the clamp test remains limited. The TG/HDL-C ratio offers a pragmatic alternative, enabling frontline healthcare workers to screen for metabolic risk efficiently (Baneu et al., 2024; Colantoni et al., 2024). Incorporating this marker into primary care could support early identification, guiding lifestyle interventions and preventing progression to T2DM and CVD (Kosmas et al., 2023; Ofori et al., 2024).

This study has several strengths. First, it leverages a well-characterised cohort of young adults, offering insights into early-life metabolic risk. Second, the comprehensive biomarker analysis, combined with rigorous ROC and multivariable modelling, strengthens the validity of our conclusions. The focus on a rural South African setting also enhances relevance for LMICs, where resource limitations necessitate simple screening solutions.

However, limitations must be acknowledged. The cross-sectional design precludes causal inference. Reliance on HOMA-IR, though validated, may underestimate or misclassify IR compared to clamp techniques. The absence of confounders such as BMI, waist circumference, and lifestyle variables limits adjustment in regression models. Finally, generalisability is constrained to young, semi-rural Black South Africans, and further research is needed in urban, older, and multi-ethnic populations.

In conclusion, the TG/HDL-C ratio demonstrated superior predictive accuracy for IR compared to individual lipid markers in young adults from Lephalale. Its low cost, simplicity, and strong diagnostic value support its use as a frontline screening tool in rural primary care. Policymakers should consider integrating TG/HDL-C ratio into routine practice, alongside community-based lifestyle interventions, to curb the rising burden of metabolic diseases in South Africa.

Conclusions

This cross-sectional study demonstrates that the triglyceride-to-HDL cholesterol (TG/HDL-C) ratio is a strong, low-cost predictor of insulin resistance in young adults from rural South Africa. Elevated TG, low HDL-C, and especially a high TG/HDL-C ratio were independently associated with insulin resistance. Given its simplicity, affordability, and low burden, the TG/HDL-C ratio should be integrated into routine screening protocols for early identification of metabolic risk in resource-limited settings.

The TG/HDL-C ratio emerged as a robust, independent predictor of IR across both diabetic and non-diabetic participants, and across sexes, with high sensitivity and specificity. Its strong predictive value, simplicity of calculation, and reliance on routine lipid panel components make it a promising surrogate marker for early identification of metabolic risk in low-resource, rural settings.

These findings highlight the importance of integrating lipid ratio assessments into screening protocols for metabolic disorders among young adults, particularly in underserved populations. Longitudinal research is needed to confirm the utility of the TG/HDL-C ratio in predicting future cardiometabolic outcomes and to inform targeted interventions aimed at reducing the burden of insulin resistance and its complications in similar contexts. Importantly, the TG/HDL-C ratio represents a low-cost, simple, and low-burden test that can be incorporated into routine care in resource-limited rural settings.

Acknowledgements

The authors extend their heartfelt gratitude to the Ellisras Longitudinal Study team and participants for their vital role in this research. Their commitment and willingness to share data were instrumental in the completion of this study, and we deeply appreciate their contributions.

Disclosure statement

The authors declare no financial or personal conflicts of interest that could have influenced the development of this article.

Disclaimer

The opinions and conclusions presented in this article are those of the authors alone and do not necessarily reflect the views or policies of their affiliated institutions or funding bodies.

Funding

This research was not supported by any specific funding from public, commercial, or non-profit organisations.

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Data availability statement

The raw data utilized in this study were sourced from the Ellisras Longitudinal Study (ELS). Processed data supporting the results of this research can be obtained from co-author K.D.M. upon reasonable request via email at Kotsedi.Monyeki@ul.ac.za. Access to these data is subject to certain restrictions, as they were provided under a specific licensing agreement for use in this study.

References

- Armanini, D., Boscaro, M., Bordin, L., & Sabbadin, C. (2022). Controversies in the pathogenesis, diagnosis and treatment of PCOS: focus on insulin resistance, inflammation, and hyperandrogenism. *International Journal of Molecular Sciences*, 23(8), 4110. <https://doi.org/10.3390/ijms23084110>
- Baneu, P., Văcărescu, C., Drăgan, S.-R., Cirin, L., Lazăr-Höcher, A.-I., Cozgarea, A., Faur-Grigori, A.-A., Crișan, S., Gaiță, D., Luca, C.-T., & Cozma, D. (2024). The triglyceride/HDL ratio as a surrogate biomarker for insulin resistance. *Biomedicines*, 12(7), 1493. <https://doi.org/10.3390/biomedicines12071493>
- Colantoni, A., Bucci, T., Cocomello, N., Angelico, F., Ettorre, E., Pastori, D., Lip, G. Y. H., Del Ben, M., & Baratta, F. (2024). Lipid-based insulin-resistance markers predict cardiovascular events in metabolic dysfunction associated steatotic liver disease. *Cardiovascular Diabetology*, 23(1), 175. <https://doi.org/10.1186/s12933-024-02263-6>
- Cornejo, M., Fuentes, G., Valero, P., Vega, S., Grismaldo, A., Toledo, F., Pardo, F., Moore-Carrasco, R., Subiabre, M., Casanello, P., Faas, M. M., van Goor, H., & Sobrevia, L. (2021). Gestational diabetes and placental vascular dysfunction. *Acta Physiologica (Oxford, England)*, 232(4), e13671. <https://doi.org/10.1111/apha.13671>
- Deery, H. A., Zhang, J., Hensley, K. S., et al. (2024). Peripheral insulin resistance attenuates cerebral glucose uptake and β -cell secretory capacity in older adults. *Nature Metabolism*, 6(2), 178–190. <https://doi.org/10.1038/s44324-024-00019-0>
- ElSayed, N. A., Aleppo, G., Aroda, V. R., Bannuru, R. R., Brown, F. M., Bruemmer, D., Collins, B. S., Gaglia, J. L., Hilliard, M. E., Isaacs, D., Johnson, E. L., Kahan, S., Khunti, K., Leon, J., Lyons, S. K., Perry, M. L., Prahalad, P., Pratley, R. E., Seley, J. J., Stanton, R. C., & Gabbay, R. A., American Diabetes Association. (2023). 2. Classification and diagnosis of diabetes: standards of medical care in diabetes—2023. *Diabetes Care*, 46(Supplement_1), S19–S40. <https://doi.org/10.2337/dc23-S002>
- Frankowski, R., Kobierecki, M., Wittczak, A., Różycka-Kosmalska, M., Pietras, T., Sipowicz, K., & Kosmalski, M. (2023). Type 2 diabetes mellitus, non-alcoholic fatty liver disease, and metabolic repercussions: the vicious cycle and its interplay with inflammation. *International Journal of Molecular Sciences*, 24(11), 9677. <https://doi.org/10.3390/ijms24119677>
- Freeman, A. M., & Pennings, N. (2023). Insulin resistance. In *StatPearls*. [Internet]. StatPearls Publishing. <https://doi.org/10.1016/B978-0-12-819162-6.00001-2>
- Ganeva, S. S., Rayanova, G. H., Todorova, K. N., Lukanov, T. H., & Blazheva, S. O. (2021). The role of triglyceride to HDL cholesterol ratio as a clinical surrogate marker for cardiovascular risk and insulin resistance in patients with metabolic syndrome. *Journal of Biomedical and Clinical Research*, 14(2), 162–168. <https://doi.org/10.2478/jbcr-2021-0012>
- Guo, W., Song, Y., Sun, Y., Du, H., Cai, Y., You, Q., Fu, H., & Shao, L. (2022). Systemic immune-inflammation index is associated with diabetic kidney disease in type 2 diabetes mellitus patients: evidence from NHANES 2011–2018. *Frontiers in Endocrinology*, 13, 1071465. <https://doi.org/10.3389/fendo.2022.1071465>
- International Diabetes Federation. (2021). *IDF diabetes atlas*. 10th ed. Available from: <https://www.diabetesatlas.org>
- Khan, K., Quazi, S., Bankar, N. J., Wanjari, A., Gosavi, R., Joshi, P., & Gupta, S. (2024). A cross-sectional observational study to assess the efficacy of triglyceride to high-density lipoprotein ratio as a marker of insulin resistance in subjects of central rural India. *Cureus*, 16(4), e58612. <https://doi.org/10.7759/cureus.58612>

- Kopp, W. (2024). Aging and “Age-Related” diseases—What is the relation? *Aging and Disease*, 14(2), 0. <https://doi.org/10.14336/ADMET.2024.0101>
- Kosmas, C. E., Rodriguez Polanco, S., Bousvarou, M. D., Papakonstantinou, E. J., Peña Genao, E., Guzman, E., & Kostara, C. E. (2023). The triglyceride/high-density lipoprotein cholesterol (TG/HDL-C) ratio as a risk marker for metabolic syndrome and cardiovascular disease. *Diagnostics (Basel, Switzerland)*, 13(5), 929. <https://doi.org/10.3390/diagnostics13050929>
- Kosmas, C. E., Rodriguez Polanco, S., Bousvarou, M. D., Papakonstantinou, E. J., Peña Genao, E., Guzman, E., & Kostara, C. E. (2023). The TG/HDL-C ratio as a risk marker for metabolic syndrome and cardiovascular disease. *Diagnostics (Basel)*, 13(5), 929. <https://doi.org/10.3390/diagnostics13050929>
- Kruger, R., Monyeki, M. A., Schutte, A. E., Smith, W., Mels, C. M. C., Kruger, H. S., Pienaar, A. E., Gafane-Mateman, L. F., Breet, Y., Lammertyn, L., Mokwasi, G. G., Kruger, A., Deacon, E., & Hanssen, H. (2020). The exercise, arterial modulation and nutrition in youth South Africa study (ExAMIN youth SA). *Frontiers in Pediatrics*, 8, 212. <https://doi.org/10.3389/fped.2020.00212>
- Lee, Y. C., Lee, J. W., & Kwon, Y. J. (2022). Comparison of the triglyceride glucose (TyG) index, TG/HDL-C ratio, and METS-IR associated with periodontitis in Korean adults. *Therapeutic Advances in Chronic Disease*, 13, 20406223221122671. <https://doi.org/10.1177/20406223221122671>
- Li, M., Chi, X., Wang, Y., Setrerrahmane, S., Xie, W., & Xu, H. (2022). Trends in insulin resistance: Insights into mechanisms and therapeutic strategy. *Signal Transduction and Targeted Therapy*, 7(1), 216. <https://doi.org/10.1038/s41392-022-01073-0>
- Luo, Y., Wang, H., Gao, J., et al. (2024). Pediatric obesity and insulin resistance: mechanisms and management. *J Obes*, 2024, 2298306. <https://doi.org/10.1155/2024/2298306>
- Mahdavi-Roshan, M., Mozafarihashjin, M., Shoaibinobarian, N., Ghorbani, Z., Salari, A., Savarrakhsh, A., & Hekmatdoost, A. (2022). Evaluating the use of novel atherogenicity indices and insulin resistance surrogate markers in predicting the risk of coronary artery disease: a case-control investigation with comparison to traditional biomarkers. *Lipids in Health and Disease*, 21(1), 126. <https://doi.org/10.1186/s12944-022-01732-9>
- Metwally, A. A., Ahn, A., Omranian, S., et al. (2025). Insulin resistance prediction from wearables and routine blood biomarkers. *arXiv [Preprint]*. <https://doi.org/10.48550/arXiv.2505.03784>
- Minja, N. W., Nakagaayi, D., Aliku, T., Zhang, W., Ssinabulya, I., Nabaale, J., Amutuhaire, W., de Loizaga, S. R., Ndagire, E., Rwebembera, J., Okello, E., & Kayima, J. (2022). Cardiovascular disease burden in Africa: epidemiology, risk factors, and opportunities. *Frontiers in Cardiovascular Medicine*, 9, 1008335. <https://doi.org/10.3389/fcvm.2022.1008335>
- Ofori, B., Twum, S., Yeboah, S. N., Ansah, F., & Sarpong, K. A. N. (2024). Towards the development of cost-effective point-of-care diagnostic tools for poverty-related infectious diseases in sub-Saharan Africa. *PeerJ*, 12, e17198. <https://doi.org/10.7717/peerj.17198>
- Okop, K. J., Micklesfield, L. K., Puoane, T., et al. (2025). Body image perception and 10-year cardiovascular disease risk among urban black South Africans. *BMC Public Health*, 25, 112. <https://doi.org/10.1186/s12889-025-20015-1>
- Park, S. Y., Gautier, J.-F., & Chon, S. (2021). Assessment of insulin secretion and insulin resistance in humans: methods and applications. *Diabetes & Metabolism Journal*, 45(5), 641–654. <https://doi.org/10.4093/dmj.2021.0220>
- Peng, W., Liu, Y., Malowany, M., Chen, H., Su, X., & Liu, Y. (2021). Metabolic syndrome and its relation to dietary patterns among a selected urbanised and semi-urbanised Tibetan population in transition from nomadic to settled living environment. *Public Health Nutrition*, 24(5), 984–992. <https://doi.org/10.1017/S1368980019004798>
- Prashant, A., Nataraj, S. M., Swetha, N., Gowda, J., Najmunnissa, F., & Guruswamy, K. M. (2024). Unveiling the significance of surrogate markers of insulin resistance in metabolic health assessment. *Indian Journal of Medical Biochemistry*, 28(2), 45–53. <https://doi.org/10.5005/jp-journals-10054-0227>
- Rodríguez-Mañas, L., Angulo, J., Carnicero, J. A., El Assar, M., García-García, F. J., & Sinclair, A. J. (2022). Dual effects of insulin resistance on mortality and function in non-diabetic older adults: findings from the Toledo study of healthy aging. *GeroScience*, 44(2), 1095–1108. <https://doi.org/10.1007/s11357-021-00384-4>
- Sharma, A. K., Gupta, S., Chaturvedi, A., et al. (2023). Dysbiosis versus diabetes: signaling pathways and therapeutic perspectives. *Drug Discov Today*, 28(5), 1414–1424. <https://doi.org/10.1016/j.drudis.2022.11.016>
- Tejera, C. H., Minnier, J., Fazio, S., Safford, M. M., Colantonio, L. D., Irvin, M. R., Howard, V., Zakai, N. A., & Pamir, N. (2021). High triglyceride to HDL cholesterol ratio is associated with increased coronary heart disease among White but not Black adults. *American Journal of Preventive Cardiology*, 7, 100198. <https://doi.org/10.1016/j.ajpc.2021.100198>
- Tong, Y., Chen, C., Shi, W., et al. (2022). Obesity and insulin resistance: pathophysiology insights. *Clinical Science*, 136(10), 1143–1162. <https://doi.org/10.1042/CS20220129>
- Wali, J. A., Rondas, D., McKenzie, M. D., et al. (2021). Macronutrient roles in obesity and insulin resistance. *Biology (Basel)*, 10(4), 336. <https://doi.org/10.3390/biology10040336>
- Walker, R. J., Patel, M., Kalane, B., et al. (2024). Material needs security and cardiovascular risk factors in rural South Africa. *Preventing Chronic Disease*, 21, E08. <https://doi.org/10.5888/pcd21.220435>
- Yuan, J., He, X., Lu, Y., Pu, X., Liu, L., Zhang, X., Liao, J., Li, G., Luo, Y., & Zhang, T. (2025). Triglycerides/high-density lipoprotein-cholesterol ratio outperforms traditional lipid indicators in predicting metabolic dysfunction-associated steatotic liver disease among U.S. adults. *Frontiers in Endocrinology*, 16, 1591241. <https://doi.org/10.3389/fendo.2025.1591241>