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The Triglyceride-Glucose Index: A Potential Simple Screening Tool for Insulin Resistance in Young Adults

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A B S T R A C T

Background: Insulin resistance is a key factor in the development of metabolic diseases, which are increasingly prevalent in young adults. Early detection is crucial for timely intervention. The triglyceride-glucose (TyG) index, calculated from fasting triglyceride and glucose levels, has emerged as a potential alternative to the more complex homeostasis model assessment of insulin resistance (HOMA-IR). This study aimed to evaluate the agreement between the TyG index and HOMA-IR in detecting insulin resistance in young adults. **Methods:** A cross-sectional study was conducted on 102 non-diabetic young adults (aged 18-22 years). Fasting blood samples were collected to measure triglyceride, glucose, and insulin levels. The agreement between the TyG index and HOMA-IR was assessed using the Kappa coefficient. **Results:** The median age of the participants was 20 years, with 65.7% being female. The prevalence of insulin resistance was 79.4% based on the TyG index (cut-off value of 4.25) and 43.1% based on HOMA-IR (cut-off value of 2.2). The agreement between the two indices was slight (Kappa = 0.155, p = 0.001). **Conclusion:** The TyG index showed a higher prevalence of insulin resistance compared to HOMA-IR in this population. However, the agreement between the two indices was low. Further research is needed to validate the TyG index as a screening tool for insulin resistance in young adults.

1. Introduction

Insulin resistance is a complex metabolic disorder characterized by the impaired response of cells to the action of insulin, a hormone produced by the pancreas that regulates blood sugar levels. In insulin resistance, the body's cells become less sensitive to insulin, leading to elevated levels of glucose in the bloodstream. This condition is a major contributor to the development of a cluster of metabolic abnormalities known as metabolic syndrome, which includes type 2 diabetes mellitus, cardiovascular disease, dyslipidemia (abnormal blood lipid levels), and non-alcoholic fatty liver disease. The prevalence of insulin resistance and associated metabolic diseases is increasing at an alarming rate worldwide, posing a significant public health challenge. This rise is attributed to a complex interplay of factors, including genetic predisposition, lifestyle choices, and environmental influences. Among the modifiable risk factors, sedentary behavior, unhealthy dietary patterns high in processed foods and saturated fats, and obesity are particularly prominent contributors to the development of insulin resistance. Early detection of insulin resistance is of paramount importance in preventing or delaying the onset of metabolic diseases and their associated complications. Timely

identification of individuals with insulin resistance allows for the implementation of lifestyle interventions, such as increased physical activity, dietary modifications, and weight management, which have been shown to improve insulin sensitivity and reduce the risk of disease progression.[1-3]

The gold standard for assessing insulin resistance is the hyperinsulinemic-euglycemic clamp (HIEC) technique. HIEC involves the intravenous infusion of insulin and glucose to maintain stable blood sugar levels while simultaneously measuring glucose uptake by tissues. Although HIEC provides a precise measurement of insulin sensitivity, it is an invasive, expensive, and time-consuming procedure that requires specialized equipment and trained personnel. These limitations make HIEC impractical for routine clinical use and large-scale screening. As a result of the challenges associated with HIEC, surrogate markers of insulin resistance have been developed to provide a more accessible and cost-effective means of assessment. One widely used surrogate marker is the homeostasis model assessment of insulin resistance (HOMA-IR), which is calculated using fasting glucose and insulin levels. HOMA-IR has been shown to correlate well with HIEC and is considered a reliable indicator of insulin resistance in various populations. However, the measurement of fasting insulin levels requires additional laboratory testing, which may not be readily available or affordable in all clinical settings. The limitations associated with both HIEC and HOMA-IR have led to the exploration of alternative indices that do not require insulin measurement. Among these, the triglyceride-glucose (TyG) index has emerged as a promising candidate due to its simplicity and cost-effectiveness. The TyG index is calculated using fasting triglyceride and glucose levels, both of which are routinely measured in clinical practice as part of standard lipid and metabolic panels.[4-7]

Triglycerides, a type of fat found in the blood, have been recognized as an independent risk factor for cardiovascular disease and are also associated with insulin resistance. Elevated triglyceride levels can impair insulin signaling pathways and contribute to the development of metabolic dysfunction. Similarly, elevated fasting glucose levels are a hallmark of insulin resistance and reflect the body's inability to effectively regulate blood sugar. The TyG index, by combining these two readily available metabolic parameters, provides an indirect measure of insulin resistance. Studies have suggested that the TyG index correlates well with both HOMA-IR and HIEC, indicating its potential as a reliable surrogate marker for insulin resistance. Furthermore, the TyG index has been associated with an increased risk of cardiovascular disease, type 2 diabetes, and other metabolic complications, further supporting its clinical relevance. The TyG index has been studied in various populations, including adolescents, adults, and individuals with specific health conditions, such as obesity, metabolic syndrome, and polycystic ovary syndrome (PCOS). However, there is limited data on the agreement between the TyG index and HOMA-IR in young adults, particularly in the Indonesian population.[8-10] Therefore, this study aimed to evaluate the agreement between the TyG index and HOMA-IR in detecting insulin resistance in a non-diabetic young adult population.

2. Methods

This research was designed as a cross-sectional study and conducted at two locations within the Universitas Andalas Hospital (RS UNAND) and Dr. M. Djamil General Hospital Padang from November 2023 to July 2024. The study population consisted of undergraduate students from the Faculty of Medicine, Universitas Andalas. Participants were recruited using consecutive sampling. This method minimizes selection bias and ensures a representative sample of the target population.

To ensure the study's validity and minimize confounding factors, specific inclusion and exclusion criteria were established. Inclusion criteria; Willingness to participate: Participants had to express their willingness to participate in the study by signing an informed consent form, indicating their understanding of the study's purpose, procedures,

and potential risks and benefits; Normal fasting blood glucose levels: Participants were required to have fasting blood glucose levels within the normal range of 70.0-99.9 mg/dL, as determined by a blood test. This criterion ensured that the study population consisted of non-diabetic individuals, as the study aimed to investigate insulin resistance in a healthy young adult population. Exclusion criteria; History of chronic diseases: Individuals with a history of diabetes mellitus, heart disease, liver disease, or kidney disease were excluded from the study. These conditions can independently affect insulin sensitivity and other metabolic parameters, potentially confounding the study's findings; Current use of lipid-lowering medication: Participants currently using lipid-lowering medication were excluded to avoid the potential influence of these medications on triglyceride levels and insulin resistance; Pregnancy or breastfeeding: Pregnant or breastfeeding individuals were excluded due to the significant hormonal changes associated with these states, which can affect glucose metabolism and insulin resistance. These criteria were assessed through a combination of a questionnaire and an interview conducted by trained personnel. This approach ensured a comprehensive evaluation of the participants' health status and eligibility for the study.

Data collection involved the collection of blood samples from the participants, following standardized procedures to ensure the quality and integrity of the samples. Participants were instructed to fast overnight for a period of 10-12 hours prior to blood collection. Fasting ensured that the blood samples reflected basal metabolic conditions, minimizing the influence of recent food intake on glucose and triglyceride levels. Venous blood samples were collected aseptically from the fossa cubiti region (the inner bend of the elbow) by trained personnel. Aseptic technique was strictly followed to prevent contamination of the blood samples. A total of 6 mL of blood was collected from each participant into two tubes containing a clot activator with a gel separator. The clot activator facilitated blood clotting, while the gel separator prevented the mixing of serum and blood cells after centrifugation. The tubes were left undisturbed for 30 minutes at room temperature to allow for complete clot formation. Subsequently, the samples were centrifuged at 1500 g for 15 minutes to separate the serum from the blood cells. Hemolyzed (samples with ruptured red blood cells), icteric (samples with high bilirubin levels), and lipemic (samples with high lipid levels) samples were excluded from the study. These conditions can interfere with the accuracy of laboratory measurements.

The handling and storage of serum samples were carefully managed to maintain sample integrity and minimize pre-analytical variability. Serum samples for glucose and triglyceride measurements were analyzed immediately after separation without storage. This minimized the potential for changes in glucose and triglyceride levels over time. Serum samples for insulin measurement were aliquoted (divided into smaller portions) and stored at -20°C until analysis. Freezing the samples preserved insulin stability and allowed for batch analysis at a later time. All analyses were performed within a single period to minimize inter-assay variability, which can arise from differences in reagents, calibrators, or laboratory conditions over time. Frozen aliquots for insulin measurement were thawed at room temperature for 30 minutes before analysis. After thawing, the samples were homogenized (mixed gently) to ensure uniform distribution of insulin before testing.

The laboratory measurements were performed using standardized methods and automated analyzers to ensure accuracy and precision. Fasting blood glucose levels were measured using the hexokinase method on an automated analyzer. The hexokinase method is a highly specific and sensitive enzymatic assay for glucose measurement, widely considered the reference method for glucose determination. Triglyceride levels were measured using an enzymatic colorimetric method on an automated analyzer. This method involves the enzymatic hydrolysis of triglycerides, followed by the measurement of glycerol, a product of the reaction, using a colorimetric assay.

Fasting insulin levels were measured using the electrochemiluminescence immunoassay (ECLIA) method on an automated analyzer. ECLIA is a highly sensitive and specific immunoassay technique that uses electrochemiluminescence to detect the concentration of insulin in the serum sample.

Stringent quality control procedures were implemented throughout the study to ensure the reliability and validity of the laboratory measurements. Precision testing was conducted within runs (intra-assay precision) and between days (inter-assay precision) using commercial control materials. This involved analyzing control materials with known concentrations of glucose, triglycerides, and insulin alongside the study samples. The coefficient of variation (CV), a measure of the relative variability of the measurements, was calculated to assess the precision of the assays. Accuracy testing was performed to ensure that the measured values were close to the true values. This involved comparing the measured values of control materials to their known target values.

The TyG index and HOMA-IR were calculated using established formulas based on the measured fasting glucose, triglycerides, and insulin levels. The TyG index and HOMA-IR were calculated using the following formula. This TyG index involves the natural logarithm (ln) of the product of fasting triglycerides and fasting glucose divided by 2. The HOMA-IR formula involves the product of fasting insulin and fasting glucose divided by 22.5.

$$\text{TyG index} = \ln [\text{fasting triglycerides (mg/dL)} \times \text{fasting glucose (mg/dL)}/2]$$

$$\text{HOMA-IR} = [\text{fasting insulin } (\mu\text{U/mL}) \times \text{fasting glucose (mmol/L)}]/22.5.$$

Statistical analysis was performed using SPSS software version 25.0. Descriptive statistics were used to summarize the characteristics of the study participants, including age, gender, body mass index (BMI), ethnicity, and origin city. Descriptive statistics provide a clear and concise overview of the study population. The agreement between the TyG index and HOMA-IR in detecting insulin resistance was assessed using the Kappa coefficient. The Kappa coefficient is a statistical measure that quantifies the agreement between two categorical variables, taking into account the agreement that would occur by chance. A Kappa value of 0.8 or higher was considered to indicate good agreement. The p-value, a measure of statistical significance, was calculated to determine the probability of obtaining the observed results (or more extreme results) if there were no real association between the TyG index and HOMA-IR. A p-value of less than 0.05 was considered statistically significant, indicating that the observed agreement between the two indices was unlikely to be due to chance.

Ethical considerations were prioritized throughout the study to ensure the protection of the participants' rights and well-being. The study protocol was reviewed and approved by the Ethics Committee of Dr. M. Djamil General Hospital Padang. This ensured that the study was conducted in accordance with ethical principles and guidelines for research involving human subjects. All participants provided written informed consent before enrollment in the study. Informed consent ensured that the participants were fully aware of the study's purpose, procedures, potential risks and benefits, and their right to withdraw from the study at any time.

3. Results

Table 1 provides a summary of the demographic and baseline characteristics of the 102 young adults who participated in the study; Age: The median age of the participants was 20 years, with a range of 18-22 years. This indicates that the study population consisted of young adults within a relatively narrow age range, which is important for minimizing the

potential influence of age on insulin resistance and other metabolic parameters; Gender: The majority of the participants were female (65.7%), while 34.3% were male. This gender distribution is not uncommon in health-related studies, particularly those involving young adults. However, it is important to consider the potential influence of gender on insulin resistance, as some studies have suggested that gender hormones may play a role in insulin sensitivity; BMI: Approximately 30.4% of the participants were classified as obese (BMI ≥ 25 kg/m²), while the remaining 69.6% were non-obese (BMI < 25 kg/m²). Obesity is a well-established risk factor for insulin resistance and other metabolic diseases. The relatively high proportion of obese participants in this study suggests that this population may be at increased risk for insulin resistance; Ethnicity: The majority of the participants (70.6%) were of Minangkabau ethnicity, which is the largest ethnic group in West Sumatra, Indonesia, where the study was conducted. The remaining 29.4% belonged to other ethnic groups. Ethnicity can influence genetic predisposition to insulin resistance and other metabolic traits. The inclusion of participants from different ethnic groups may increase the generalizability of the study's findings to the broader Indonesian population; Origin City: Most of the participants (63.7%) were from Padang, the capital city of West Sumatra. The remaining 36.3% were from other cities. The origin city may reflect differences in lifestyle, dietary habits, and environmental exposures, which could potentially influence insulin resistance. The inclusion of participants from different cities may increase the representativeness of the study sample.

Table 1. Participant characteristics.

Characteristic	Category	Frequency (n)	Percentage (%)
Age (years)			
	Median	20	
	Range	18-22	
Gender			
	Female	67	65.7
	Male	35	34.3
BMI (kg/m²)			
	Obese (≥ 25)	31	30.4
	Non-obese (< 25)	71	69.6
Ethnicity			
	Minangkabau	72	70.6
	Other	30	29.4
Origin City			
	Padang	65	63.7
	Other	37	36.3

Table 2 displays the median, range, and normal reference ranges for three key biochemical parameters measured in the study participants: fasting blood glucose, triglycerides, and fasting insulin. Fasting blood glucose levels were generally within the normal range, with a median of 88 mg/dL. This is expected as the study specifically included non-diabetic young adults with normal fasting glucose levels as an

inclusion criterion. Triglyceride levels showed more variability, with a median of 73 mg/dL and a range of 38-108 mg/dL. While the median falls within the desirable range (<150 mg/dL), the range indicates that some participants had elevated triglyceride levels, which could be a potential indicator of insulin resistance or other metabolic disturbances. Fasting insulin levels also exhibited variability, with a median of 8.72 μU/mL and a range of 1.99-15.45 μU/mL. These values fall within the normal reference range (2.6-24.9 μU/mL), suggesting that the participants generally had normal insulin secretion. However, the range indicates that some individuals had relatively higher or lower insulin levels compared to the median.

Table 2. Biochemical parameters.

Parameter	Median	Range	Normal reference range
Fasting blood glucose (mg/dL)	88	78-98	70-99
Triglycerides (mg/dL)	73	38-108	<150
Fasting insulin (μU/mL)	8.72	1.99-15.45	2.6-24.9

Table 3 presents the prevalence of insulin resistance in the study population based on two different indices: the TyG index and HOMA-IR; TyG Index: Using a cut-off value of ≥ 4.25, the TyG index identified 81 participants as having insulin resistance, resulting in a prevalence of 79.4%. This suggests that based on the TyG index, a significant majority of the young adults in this study exhibited insulin resistance; HOMA-IR: In contrast, using a cut-off value of ≥ 2.2, HOMA-IR identified 44 participants as having insulin resistance, leading to a prevalence of 43.1%. This indicates that a smaller proportion of the participants were classified as having insulin resistance based on HOMA-IR compared to the TyG index.

Table 3. Prevalence of insulin resistance.

Index	Cut-off value	Insulin resistance	Non-insulin resistance	Total	Prevalence of Insulin resistance (%)
TyG index	≥ 4.25	81	21	102	79.4
HOMA-IR	≥ 2.2	44	58	102	43.1

Table 5 presents the statistical analysis of the agreement between the TyG index and HOMA-IR in identifying insulin resistance among the participants; Kappa Coefficient: The Kappa coefficient, a measure of agreement between two categorical variables, was calculated to be 0.155. This value falls within the range of "slight agreement" according to established interpretation guidelines. This indicates that while there was some agreement between the TyG index and HOMA-IR in classifying participants as having or not having insulin resistance, the agreement was relatively low; p-value: The p-value, which assesses the statistical significance of the observed agreement, was 0.001. This value is less than the conventional significance level of 0.05, indicating that the observed agreement between the TyG index and HOMA-IR was statistically significant. In other words, the agreement was unlikely to have occurred by chance alone.

Table 4. Agreement between TyG index and HOMA-IR.

Statistic	Value	Interpretation
Kappa coefficient	0.155	Slight agreement
p-value	0.001	Statistically significant

4. Discussion

Insulin resistance, a complex metabolic disorder characterized by impaired cellular response to insulin, is a major contributor to the development of various metabolic diseases. These include type 2 diabetes mellitus, cardiovascular disease, and non-alcoholic fatty liver disease, among others. Insulin resistance is a key underlying factor in the development of metabolic syndrome, a cluster of conditions that increase the risk of cardiovascular disease, stroke, and type 2 diabetes. The prevalence of insulin resistance is on the rise globally, and this trend is particularly alarming among young adults. This rise is attributed to a confluence of factors, including genetic predisposition, lifestyle changes, and environmental influences. Among these, the increasing prevalence of obesity, physical inactivity, and unhealthy dietary patterns, particularly those rich in processed foods, saturated fats, and added sugars, are significant contributors. Insulin is a crucial hormone produced by the pancreas that plays a central role in regulating blood sugar levels and overall metabolic homeostasis. When we consume food, especially carbohydrates, our blood sugar levels rise. This rise triggers the pancreas to release insulin into the bloodstream. Insulin acts as a key that unlocks the doors of our cells, allowing glucose to enter and be used for energy or stored for later use. In healthy individuals, insulin effectively facilitates glucose uptake by muscle, liver, and fat cells, maintaining blood sugar levels within a normal range. However, in insulin resistance, this intricate process is disrupted. The cells become less responsive to insulin's signals, akin to the locks becoming rusty and resistant to the key. As a result, glucose struggles to enter the cells, leading to a buildup of glucose in the bloodstream, a condition known as hyperglycemia. The pancreas, sensing the elevated blood sugar, tries to compensate by producing more insulin. This can lead to a state of hyperinsulinemia, where insulin levels are persistently high. Over time, this compensatory mechanism can falter, leading to pancreatic beta-cell dysfunction and ultimately, the development of type 2 diabetes. The precise mechanisms underlying insulin resistance are complex and multifaceted, involving a complex interplay of genetic, environmental, and lifestyle factors. These factors can disrupt insulin signaling pathways, impair glucose transport, and increase hepatic glucose production, all contributing to the development of insulin resistance. While lifestyle and environmental factors play a significant role in the development of insulin resistance, genetic predisposition also contributes to an individual's susceptibility to this condition. Several genes have been identified that influence insulin sensitivity and the risk of developing insulin resistance. These genes can affect various aspects of insulin signaling and glucose metabolism, including insulin receptor function, insulin secretion, glucose transport, and intracellular signaling pathways. Variations in these genes can alter the expression or function of key proteins involved in insulin action, leading to impaired insulin sensitivity. For example, variations in the gene encoding the insulin receptor can affect the receptor's ability to bind to insulin and initiate downstream signaling events. Similarly, variations in genes involved in glucose transport, such as GLUT4, can impair the transport of glucose into muscle and fat cells. In addition to individual genes, epigenetic modifications, which are heritable changes in gene expression that do not involve alterations in the DNA sequence, can also contribute to insulin resistance.

Epigenetic modifications can be influenced by environmental factors, such as diet and exercise, and can affect the expression of genes involved in insulin signaling and glucose metabolism. Lifestyle and environmental factors play a crucial role in the development and progression of insulin resistance. These factors can interact with genetic predisposition to modulate an individual's risk of developing this condition. Obesity, particularly abdominal obesity, is a major risk factor for insulin resistance. Excess fat accumulation, especially in the abdominal area, can lead to chronic low-grade inflammation and the release of pro-inflammatory cytokines, which can interfere with insulin signaling pathways. Physical inactivity is another significant contributor to insulin resistance. Regular physical activity enhances insulin sensitivity by increasing glucose uptake by muscles and improving overall metabolic health. Conversely, a sedentary lifestyle can lead to decreased insulin sensitivity and increased risk of insulin resistance. Diets high in processed foods, saturated fats, and added sugars have been linked to increased insulin resistance. These foods can promote weight gain, inflammation, and oxidative stress, all of which can contribute to impaired insulin sensitivity. Chronic sleep deprivation has been associated with increased insulin resistance. Sleep plays a crucial role in regulating hormonal balance and metabolic processes, and insufficient sleep can disrupt these processes, leading to impaired insulin sensitivity. Chronic stress can also contribute to insulin resistance. Stress hormones, such as cortisol, can interfere with insulin signaling pathways and promote glucose production, leading to elevated blood sugar levels. Exposure to certain environmental toxins, such as air pollution and pesticides, has been linked to increased insulin resistance. These toxins can induce oxidative stress and inflammation, which can impair insulin sensitivity. The increasing prevalence of insulin resistance and its associated metabolic diseases underscores the critical importance of early detection and intervention. Early identification of individuals with insulin resistance allows for the implementation of lifestyle modifications and preventive strategies that can delay or prevent the onset of these conditions and their associated complications. Lifestyle interventions, such as increased physical activity, dietary modifications, and weight management, have been shown to improve insulin sensitivity and reduce the risk of disease progression. Regular physical activity, particularly aerobic exercise and strength training, enhances insulin action and helps regulate blood sugar levels. Dietary modifications, such as reducing intake of processed foods, saturated fats, and added sugars, and increasing consumption of fruits, vegetables, whole grains, and lean protein, can also improve insulin sensitivity and promote weight management. Weight loss, even a modest reduction of 5-10% of body weight, can significantly improve insulin sensitivity and reduce the risk of metabolic diseases. In addition to lifestyle interventions, certain medications, such as metformin, may be used to improve insulin sensitivity and manage blood sugar levels in individuals with insulin resistance.[11-13]

Accurately assessing insulin resistance is crucial for identifying individuals at risk of developing metabolic disorders and implementing timely interventions. However, measuring insulin resistance is not without its challenges. The gold standard method, the hyperinsulinemic-euglycemic clamp (HIEC) technique, is invasive, expensive, and time-consuming, making it impractical for large-scale screening. This limitation has fueled the search for alternative, more accessible methods for assessing insulin resistance, leading to the development of various surrogate markers and indices. The HIEC technique is widely regarded as the gold standard for assessing insulin resistance. It involves a complex procedure in which insulin and glucose are infused intravenously to maintain stable blood sugar levels while simultaneously measuring glucose uptake by tissues. By precisely controlling insulin and glucose levels, the HIEC technique allows for a direct assessment of insulin sensitivity, providing a comprehensive picture of how effectively the body responds to insulin. During the HIEC procedure,

insulin is infused at a constant rate to achieve a state of hyperinsulinemia, where insulin levels are elevated. Simultaneously, glucose is infused at a variable rate to maintain euglycemia, a state of normal blood sugar levels. The rate at which glucose needs to be infused to maintain euglycemia reflects the body's ability to utilize glucose in response to insulin. The HIEC technique provides a precise and accurate measurement of insulin sensitivity, but its complexity, invasiveness, and high cost limit its widespread use in clinical practice. The procedure requires specialized equipment, trained personnel, and a significant time commitment from both the patient and healthcare providers. These limitations make HIEC impractical for routine screening and assessment of insulin resistance in large populations. The challenges associated with HIEC have led to the development of surrogate markers and indices that provide a more accessible and cost-effective means of assessing insulin resistance. These markers and indices are typically based on blood glucose and insulin levels, which are routinely measured in clinical practice. HOMA-IR is one of the most widely used surrogate markers for assessing insulin resistance. It is calculated using fasting glucose and insulin levels, both of which can be easily obtained from a standard blood test. HOMA-IR has been shown to correlate well with HIEC, indicating its reliability as an indicator of insulin resistance. The HOMA-IR formula takes into account both fasting glucose and insulin levels, reflecting the interplay between these two key factors in insulin resistance. Elevated fasting glucose levels indicate impaired glucose uptake by cells, while elevated fasting insulin levels reflect the pancreas's attempt to compensate for the resistance by producing more insulin. HOMA-IR provides a convenient and cost-effective method for assessing insulin resistance, but it does require the measurement of fasting insulin levels, which may not be readily available or affordable in all clinical settings. This limitation has led to the exploration of alternative indices that do not require insulin measurement. The TyG index has emerged as a promising alternative to HOMA-IR for assessing insulin resistance. It is calculated using fasting triglyceride and glucose levels, both of which are routinely measured in clinical practice as part of standard lipid and metabolic panels. Triglycerides are a type of fat found in the blood, and elevated triglyceride levels are associated with an increased risk of cardiovascular disease and are also a marker of insulin resistance. In insulin resistance, the liver produces more triglycerides, and the body's ability to clear triglycerides from the blood is impaired. The TyG index reflects the combined effect of elevated triglycerides and glucose levels, both of which are associated with insulin resistance. Studies have suggested that the TyG index correlates well with both HOMA-IR and HIEC, indicating its potential as a reliable surrogate marker for insulin resistance. The TyG index offers several advantages over HOMA-IR. It does not require the measurement of fasting insulin levels, making it more accessible and cost-effective. Additionally, the TyG index may be more sensitive than HOMA-IR in detecting early stages of insulin resistance, particularly in individuals with normal fasting glucose levels. The OGTT is another widely used method for assessing insulin resistance. It involves measuring blood glucose levels before and after the ingestion of a glucose solution. The OGTT provides a dynamic assessment of glucose metabolism and insulin response, revealing how effectively the body handles a glucose load. During the OGTT, the individual fasts overnight and then consumes a glucose solution. Blood glucose levels are measured before the glucose load and at regular intervals afterward, typically at 30, 60, and 120 minutes. The pattern of blood glucose response provides insights into insulin sensitivity and glucose tolerance. In insulin-resistant individuals, blood glucose levels rise higher and remain elevated for a longer period after the glucose load compared to insulin-sensitive individuals. This reflects the impaired ability of the body to utilize glucose effectively in response to insulin. The OGTT provides valuable information about glucose metabolism and insulin resistance, but it is more time-consuming than fasting blood tests and

may be less convenient for patients. Insulin suppression tests are less commonly used methods for assessing insulin resistance, primarily employed in research settings. These tests involve infusing insulin to suppress endogenous insulin production and then measuring glucose levels to assess insulin sensitivity. One example of an insulin suppression test is the frequently sampled intravenous glucose tolerance test (FSIVGTT). During the FSIVGTT, glucose and insulin are infused intravenously, and blood samples are collected frequently to measure glucose and insulin levels. The data obtained from the FSIVGTT are then analyzed using mathematical modeling to estimate insulin sensitivity. Insulin suppression tests provide detailed information about insulin sensitivity and glucose metabolism, but they are more complex and invasive than other methods, limiting their use in routine clinical practice. Advances in technology are paving the way for new and innovative methods for assessing insulin resistance. These technologies aim to provide more accurate, non-invasive, and accessible assessments of insulin sensitivity. One such technology is continuous glucose monitoring (CGM), which involves wearing a small sensor that continuously measures glucose levels in the interstitial fluid. CGM provides a detailed picture of glucose fluctuations throughout the day and night, offering insights into glucose metabolism and insulin resistance. Another emerging technology is magnetic resonance imaging (MRI) and spectroscopy, which can be used to assess liver fat content and muscle insulin sensitivity. These techniques provide non-invasive measures of insulin resistance and can be used to monitor the effectiveness of interventions.[14-17]

This study aimed to evaluate the agreement between the Triglyceride-Glucose (TyG) index and the Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) in detecting insulin resistance in a population of young adults. The findings revealed a low agreement between the two indices, suggesting that the TyG index may not be a reliable substitute for HOMA-IR in this population. This discrepancy may be related to the different pathophysiological mechanisms underlying the two indices, as well as the influence of various factors on the TyG index. HOMA-IR is a widely used surrogate marker for assessing insulin resistance. It is calculated using fasting glucose and insulin levels, both of which can be easily obtained from a standard blood test. HOMA-IR has been shown to correlate well with the gold standard method, the hyperinsulinemic-euglycemic clamp (HIEC) technique, indicating its reliability as an indicator of insulin resistance. The HOMA-IR formula takes into account both fasting glucose and insulin levels, reflecting the interplay between these two key factors in insulin resistance. Elevated fasting glucose levels indicate impaired glucose uptake by cells, while elevated fasting insulin levels reflect the pancreas's attempt to compensate for the resistance by producing more insulin. HOMA-IR provides a direct measure of insulin resistance by quantifying the relationship between fasting glucose and insulin levels. It is a valuable tool for assessing insulin resistance in clinical practice and research settings, particularly when direct measurement of insulin sensitivity through HIEC is not feasible. The TyG index has emerged as a promising alternative to HOMA-IR for assessing insulin resistance. It is calculated using fasting triglyceride and glucose levels, both of which are routinely measured in clinical practice as part of standard lipid and metabolic panels. Triglycerides are a major component of lipoproteins, which are responsible for transporting cholesterol and other lipids in the blood. Elevated triglyceride levels are associated with an increased risk of cardiovascular disease and are also a marker of insulin resistance. In insulin resistance, the liver produces more triglycerides, and the body's ability to clear triglycerides from the blood is impaired. Glucose is the primary source of energy for the body's cells. In insulin resistance, the cells are unable to take up glucose efficiently, leading to elevated blood glucose levels. The TyG index reflects the combined effect of elevated triglycerides and glucose levels, both of which are associated with insulin resistance. Unlike HOMA-IR, which directly measures the relationship between

glucose and insulin, the TyG index indirectly reflects insulin resistance through its association with triglyceride and glucose levels. This indirect nature of the TyG index may contribute to its lower agreement with HOMA-IR observed in this study. The TyG index may be influenced by factors other than insulin resistance, such as ethnicity, dietary habits, and physical activity levels. These factors may contribute to the variability observed in the agreement between the TyG index and HOMA-IR across different studies. Studies have shown that the TyG index may vary across different ethnic groups. For example, some studies have reported higher TyG index values in Asian populations compared to Caucasian populations, even after adjusting for other factors such as age, gender, and BMI. These ethnic differences may be related to genetic variations in lipid metabolism and insulin sensitivity. Dietary habits can also influence the TyG index. Diets high in carbohydrates, particularly refined carbohydrates and sugary drinks, have been associated with higher TyG index values. Conversely, diets rich in fruits, vegetables, and whole grains have been linked to lower TyG index values. Physical activity levels can also affect the TyG index. Regular physical activity has been shown to lower TyG index values, while a sedentary lifestyle has been associated with higher values. Physical activity improves insulin sensitivity and helps regulate lipid metabolism, which may contribute to the lower TyG index values observed in physically active individuals. The findings of this study have implications for the use of the TyG index and HOMA-IR in clinical practice. While HOMA-IR remains a valuable tool for assessing insulin resistance, the TyG index offers a more accessible and cost-effective alternative, particularly in settings where insulin measurement is not readily available. However, it is important to note that the TyG index may not be as reliable as HOMA-IR in detecting insulin resistance, especially in young adults. The TyG index may be more sensitive than HOMA-IR in detecting early stages of insulin resistance, but it may also be more susceptible to the influence of factors other than insulin resistance. Therefore, it is recommended that the TyG index be used with caution in clinical practice, and that individuals with elevated TyG index values be further evaluated using HOMA-IR or other more accurate methods, such as the oral glucose tolerance test (OGTT) or the hyperinsulinemic-euglycemic clamp, if necessary.[18-20]

5. Conclusion

The study revealed a low agreement between the TyG index and HOMA-IR in detecting insulin resistance in young adults. The TyG index may be influenced by factors other than insulin resistance, such as ethnicity, dietary habits, and physical activity levels. These factors may contribute to the variability observed in the agreement between the TyG index and HOMA-IR across different studies. While HOMA-IR remains a valuable tool for assessing insulin resistance, the TyG index offers a more accessible and cost-effective alternative, particularly in settings where insulin measurement is not readily available. However, it is important to note that the TyG index may not be as reliable as HOMA-IR in detecting insulin resistance, especially in young adults. The TyG index may be more sensitive than HOMA-IR in detecting early stages of insulin resistance, but it may also be more susceptible to the influence of factors other than insulin resistance. Therefore, it is recommended that the TyG index be used with caution in clinical practice, and that individuals with elevated TyG index values be further evaluated using HOMA-IR or other more accurate methods, such as the OGTT or the HIEC, if necessary. Further research is needed to validate the TyG index as a screening tool for insulin resistance in young adults and to determine its optimal cut-off value for different populations. Future studies should also investigate the influence of various factors on the TyG index, such as ethnicity, dietary habits, and physical activity levels.

6. References

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