RESEARCH PAPER

Association of atherogenic index and TyG index with insulin resistance in apparently normal and obese/overweight children and adolescents

Running Title: Atherogenic and TyG Indices with Insulin Resistance among Children and Adolescents

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ABSTRACT

Background: The Triglyceride-Glucose (TyG) index and Atherogenic Index of Plasma (AIP) have been proposed as novel biomarkers of IR, a major pathophysiological mechanism involved in metabolism abnormalities.

Aim: To determine the relation between AIP, TyG and IR in apparently healthy and overweight/obese children and adolescents from India.

Methods: A cross-sectional study was conducted on 80 subjects, 5-14 years old, consisting of 40 obese and 40 non-obese subjects. The anthropometric parameters were measured according to WHO standards, and the BMI classification was done according to age and sex percentiles. The fasting blood samples were used to measure glucose, insulin, and lipid profile levels to calculate the TyG index, AIP and HOMA-IR. Analysis was conducted utilizing SPSS version 26.0, with a p-value < 0.05 considered significant.

Results: The findings showed that demographic factors were similar for both cases and controls, but activity level was higher for controls. Weight and BMI were significantly higher for cases ($p < 0.001$). Fasting glucose, insulin, triglyceride levels LDL-C, AIP and VLDL-C levels were significantly higher for cases ($p < 0.05$), but HDL-C was similar. Insulin resistance was identified in instances utilizing the TyG and HOMA-IR indices. TyG exhibited a substantial correlation with HOMA-IR, whereas AIP did not differ significantly between groups.

Conclusions: In conclusion, the TyG index exhibited a modest relationship with insulin resistance and could be used as a possible surrogate marker. On the other hand, the Atherogenic Index of Plasma (AIP) had inconclusive and statistically insignificant relationships with insulin resistance.

Keywords: Childhood Obesity, Dyslipidemia, Insulin Resistance (IR), Metabolic Syndrome (MetS), Triglyceride Glucose Index.

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1. INTRODUCTION

Metabolic syndrome (MetS) is a multifactorial systemic condition characterized by a cluster of interrelated variables, including insulin resistance, abdominal obesity, dyslipidemia, and hypertension, which may predispose

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individuals to cardiovascular disease (CVD) and diabetes mellitus (DM)[1].

MetS is more common in rural regions, with its worldwide prevalence attaining epidemic levels. Between the 1980s and 2012, the prevalence of Metabolic Syndrome in the United States increased by 35%[2]. Approximately 85% of people with Type 2 Diabetes Mellitus (T2DM) are simultaneously diagnosed with Metabolic Syndrome (MetS), hence elevating their vulnerability to cardiovascular diseases (CVDs)[3]. In recent years, emerging economies like India have experienced a notable increase in overweight and obesity rates among women, namely from 8.4% to 15.5% for overweight and from 2.2% to 5.1% for obesity between 1998 and 2015[4]. Swain and Chowdhury (2018) projected that around 20% of rural Indian individuals would be classified as overweight or obese by 2030[5].

The rising incidence of children's obesity and sedentary lifestyles underscores the necessity for early identification of insulin resistance (IR) to provide timely interventions targeted at preventing metabolic syndrome (MS) and its related repercussions[6]. Understanding metabolic syndrome becomes essential due to its strong association with an elevated risk of cardiovascular diseases, such as peripheral vascular disease, stroke, coronary artery disease, and type 2 diabetes.

The homeostasis model assessment of insulin resistance (HOMA-IR) and the hyperinsulinemic-euglycemic clamp are traditionally regarded as reliable indicators of insulin resistance (IR). HOMA-IR is a surrogate indicator of insulin resistance derived from the correlation between fasting glucose and insulin levels, first described by Matthews in 1985. HOMA-IR is simple, cost-effective, and closely associated with the euglycemic clamp, but its readings vary by age, gender, and ethnicity, limiting its applicability in certain groups, such as children and older adults[8, 9]. The limitations have spurred interest in non-invasive, economical, and dependable surrogate markers for evaluating insulin resistance (IR), such as the triglyceride glucose (TyG) index, a composite marker of fasting plasma glucose and triglyceride (TG) levels, acknowledged as an indicator of metabolic disturbances[10]. A newly established marker is the atherogenic index (AIP), which represents the equilibrium between atherogenic and anti-atherogenic substances[11]. The TyG index and AIP are advantageous over HOMA-IR as they rely on routine, low-cost parameters (fasting triglycerides, glucose, and HDL-C), making them accessible, non-invasive, and suitable for large-scale use across populations. TyG correlates strongly with gold-standard insulin sensitivity measures, while AIP adds insight into dyslipidemia and metabolic risk[12].

Even though TyG and AIP are effective markers of insulin resistance in worldwide research, few local studies have applied these ratios to Indian children and adolescents because of the high rates of obesity and dyslipidemia in this demographic. A distinct viewpoint on insulin sensitivity, dyslipidemia, and the TyG and AIP indices is offered by this case study. The TyG index has been suggested as a more effective diagnostic tool for insulin resistance in recent years by studies like the one by Lee et al. (2022)[13]. However, half of India's healthcare professionals are not well-versed in the use of TyG and AIP to assess the effectiveness of insulin resistance in obese and overweight children and adolescents; therefore, this study's objective was to assess how insulin resistance, the TyG, and plasma atherogenic indices relate to each other in Indian overweight or obese children and adolescents.

2. MATERIALS AND METHODS

2.1. Study Design

This cross-sectional, case-control exploration investigation was performed in compliance with the STROBE guidelines for observational research. Although causality cannot be determined, this methodology facilitated the assessment of relationships among the Triglyceride-Glucose (TyG) index, the Atherogenic Index of Plasma (AIP), and indicators of insulin resistance in children, hence providing insights for future longitudinal validation. The research was conducted from April 2021 to December 2022 in the Departments of Biochemistry and Pediatrics at a tertiary care hospital in Northern India.

2.2. Study Participants

The study included 80 children aged 5 to 14 years, consisting of 40 overweight or obese individuals (case group) and 40 age- and sex-matched children with normal weight (control group). The sample size was determined to provide sufficient statistical power, necessitating at least 35 individuals per group to get 80% power at a 95% confidence level.

2.3. Anthropometric measurements

Anthropometric measures were performed in accordance with the World Health Organization's recommendations[14]. Body weight was assessed to the closest 5 grams via a calibrated digital scale, with subjects positioned barefoot and attired in light, loose-fitting garments. Height was measured using a calibrated stadiometer while subjects were barefoot, ensuring their heels and backs were aligned with the instrument and their heads were positioned in the Frankfort horizontal plane. The Body Mass Index (BMI) was computed utilizing the formula:

$$\text{BMI} = \text{weight (kg)} / \text{height (m}^2\text{)}$$

Participants were categorized according to age- and sex-specific BMI percentiles utilizing the Asia-Pacific classification: Obese (BMI > 25.0 kg/m2), overweight (BMI 23.0–24.9 kg/m2), normal weight (BMI 18.5–22.9 kg/m2), and underweight (BMI < 18.5 kg/m2). The Kuppuswamy Scale was utilized to evaluate socioeconomic status, including education, occupation, and income, with income calculated to the 2025 Consumer Price Index, therefore classifying persons into five socioeconomic tiers[15]. Individuals with chronic medical or metabolic issues, extended drug usage, developmental or

cognitive impairments, eating disorders, or psychiatric disorders were excluded to reduce any confounding effects on the study results.

2.4. Sample Collection

Blood samples were collected from the individuals after eight hours of fasting in the morning. For each participant, 4 milliliters of venous blood were aseptically collected from the antecubital vein; 2 milliliters were transferred into a red-cap vacutainer and 2 milliliters into a grey-cap vacutainer. The samples were examined within one hour after collection. The red-cap vacutainers were centrifuged at 2000 rpm for 10 minutes to precipitate the serum, which was then used to assess the biochemical profile. Salivary samples were preserved at −20°C until further insulin testing was conducted.

2.5. Biochemical Analysis

Fasting blood glucose levels were assessed with the glucose oxidase-peroxidase enzymatic technique on an autoanalyzer. The lipid profile, comprising total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C), was assessed utilizing the enzymatic colorimetric method on the autoanalyzer (Rx Suzuka, Randox). The insulin concentrations were analyzed using the solid-phase, monoclonal antibody sandwich ELISA method, which used microwell strips covered with monoclonal antibodies and horseradish peroxidase (HRP). The color intensity generated in the reaction was directly proportional to the measured insulin concentration, which was verified against the standard curve for calculating purposes.

2.6. Index Calculations

The following indices were obtained from biochemical data and computed to evaluate the correlation between insulin resistance and metabolic risk factors:

AIP: This index was determined to maintain the viewpoint of atherogenic lipids relative to anti-atherogenic lipoproteins, indicating cardiovascular risk in dyslipidemia, and calculated using the following formula:

$$AIP = log\left(\frac{Triglycerides(\frac{mg}{dL})}{HDL - C\ (\frac{mg}{dL})}\right)$$

TyG Index: This index was used to integrate fasting glucose and triglyceride levels, serving as a viable and practical metric for assessing insulin resistance, calculated using the formula:

$$TyG = In\left(\frac{Fasting\ TGs(\frac{mg}{dL}) \times Fasting\ Glucose(\frac{mg}{dL})}{2}\right)$$

HOMA-IR: A measurement for insulin resistance utilizing fasting glucose and insulin levels; HOMA-IR was derived from the equation:

$$HOMA - IR = \left(\frac{Fasting\ Insulin\ (\frac{\mu IU}{mL}) \times Fasting\ Glucose(\frac{mmol}{L})}{22.5}\right)$$

2.7. Data Collection

Anthropometric and biochemical parameters were measured under controlled conditions. Parameters such as weight, height, and BMI were measured under controlled environmental conditions using standard procedures. In addition, the participants were required to provide fasting blood samples for the determination of biochemical parameters.

Biochemical measurement involved taking two milliliters of blood sample from the subjects and putting it in the vacutainer with a red cap for analysis of lipids, and two milliliters from the subject and putting it in a gray cap vacutainer for measurement of fasting glucose level. Insulin resistance and metabolic alterations were based on biochemical measures like AIP, TyG index, and HOMA-IR.

2.8. Ethical Consent

This study strictly followed the ethical guidelines. Written consent was obtained from all the parents or legal guardian(s) of participants. The adolescents gave their consent to take part in the study. Ethical clearance for the study was acquired from the Institutional Biomedical Research Ethics Committee (Approval Number: BREC/Th/20/BIO/06, Date: 21/12/2021).

2.9. Statistical Analysis

Data were evaluated utilizing SPSS version 26.0. Categorical variables were represented as percentages and examined with the Chi-square test, whereas continuous variables were presented as mean ± SD and evaluated using the student's t-test. Pearson's correlation was employed to investigate the correlations among biochemical and metabolic markers, while ROC curve analysis assessed the diagnostic accuracy of TyG and AIP for insulin resistance. Potential confounding variables were considered during analysis, and statistical significance was set at $p < 0.05$.

RESULTS

3.1. Demographic Characteristics

The clinicodemographic profile shows that the two samples were similar in respect to distribution by age,

gender, socioeconomic status, educational attainment, and area of residence, thus showing baseline similarity between them (Table 1). Most participants from both groups were in the age category of 8-10 years, lower middle socio-economic status, and upper primary educational attainment, being predominantly urban residents. One major difference was observed in the physical activity variable, in which the case group showed lower mean physical activity (3.75 ± 1.20 hrs per week) and a high incidence of low physical activity (30%) compared to controls (15%).

Table 1: Baseline Sociodemographic Profile And Physical Activity Levels Of Case And Control Subjects.

Parameter	Category	Case Group (n = 40)	Control Group (n = 40)
Age (years)	5–7 years	10 (25%)	14 (35%)
	8–10 years	18 (45%)	16 (40%)
	11–14 years	12 (30%)	10 (25%)
Gender	Male	22 (55%)	20 (50%)
	Female	18 (45%)	20 (50%)
Socioeconomic Status	I – Upper	2 (5%)	3 (7.5%)
	II – Upper Middle	6 (15%)	7 (17.5%)
	III – Lower Middle	18 (45%)	16 (40%)
	IV – Upper Lower	10 (25%)	11 (27.5%)
	V – Lower	4 (10%)	3 (7.5%)
Education Level (years)	1–3 years (Lower Primary)	10 (25%)	8 (20%)
	4–6 years (Upper Primary)	26 (65%)	28 (70%)
	7+ years (Middle School)	4 (10%)	4 (10%)
Area of Residence	Urban	25 (62.5%)	28 (70%)
	Rural	15 (37.5%)	12 (30%)
Physical Activity (hrs/week)	Mean ± SD	3.75 ± 1.20	4.10 ± 1.05
	Low (<3 hrs/week)	12 (30%)	6 (15%)
	Moderate (3–5 hrs/week)	24 (60%)	28 (70%)
	High (>5 hrs/week)	4 (10%)	6 (15%)

3.2. Anthropometric Measurements

The anthropometric and hemodynamic comparison between the cases and control group showed that the mean body weight of cases (40.37 kg) and BMI (22.61 kg/m²) were higher than the mean body weight of controls (32.90 kg) and BMI (17.62 kg/m²), respectively, at significance levels (p=0.001) and (p=0.00001) (Table 2). On the other hand, the mean height of both groups was relatively similar (p=0.421), meaning that there is a similarity in their linear growth. The difference in mean systolic and diastolic blood pressure between cases and controls is not statistically significant (p>0.05).

Table 2: Baseline Anthropometric Profile And Blood Pressure Measurements In Cases And Controls.

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value
Weight (kg)	40.37 ± 10.78	32.90 ± 9.63	0.001*
Range	22.8–74	17–56.3	
Height (m)	1.32 ± 0.12	1.36 ± 0.16	0.421
Range	1.1–1.6	1.08–1.89	
BMI (kg/m²)	22.61 ± 2.45	17.62 ± 1.88	0.00001*
Range	17.0–28.9	13.7–21.1	
Systolic BP (mmHg)	111.15 ± 5.7	109.2 ± 7.0	0.178
Range	100–122	96–122	
Diastolic BP (mmHg)	68.8 ± 3.3	68.0 ± 3.9	0.335
Range	62–76	60–76	

* Values are Mean ± SD. Reported p-values: Weight = 0.001*, Height = 0.421, BMI = 0.00001*, Systolic BP = 0.178, Diastolic BP = 0.335 (*significant at p < 0.05).

3.3. Biochemical Parameters

In the study (Table 3), the fasting blood glucose level was statistically significant but clinically modest differences for the cases (92.6 versus 88.22 mg/dL; p = 0.038). Also, all the measured lipid factors showed statistically significant elevations in the case group (triglyceride level

149.6 versus 124.5 mg/dL; p = 0.027; total cholesterol level 168.8 versus 150.4 mg/dL; p = 0.013; LDL-C level 96.7 versus 80.08 mg/dL; p = 0.03; and VLDL-C level 29.92 versus 24.9 mg/dL; p = 0.027), whereas the HDL-C level did not show a statistically significant elevation (p = 0.521). Moreover, higher fasting insulin levels in the case group (13.34 versus 7.3 µIU/mL).

Table 3: Comparative Evaluation Of Biochemical Parameters Between Case And Control Groups.

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value
Fasting Blood Glucose (mg/dL)	92.6 ± 13.6	88.22 ± 6.87	0.038*
Range	60–139	72–100	
Triglycerides (mg/dL)	149.6 ± 68.9	124.5 ± 73.0	0.027*
Range	79–414	35–357	
Total Cholesterol (mg/dL)	168.8 ± 41.4	150.4 ± 39.1	0.013*
Range	67–274	89–262	
HDL-C (mg/dL)	48.8 ± 12.7	46.3 ± 17.4	0.521
Range	30–91	19–87	
LDL-C (mg/dL)	96.7 ± 35.2	80.08 ± 33.13	0.03*
Range	27–195	20–153	
VLDL-C (mg/dL)	29.92 ± 13.7	24.9 ± 14.6	0.027*
Range	15.8–82.8	7–71.4	
Fasting Insulin (µIU/mL)	13.34 ± 12.1	7.3 ± 6.39	0.003*
Range	1.37–57.25	1.0–23	

Values are presented as-- (SD). The p-values for the comparison between patients and controls are as follows: HDL-C 0.521, LDL-C 0.03, VLDL-C 0.027*, FBG 0.038*, TG 0.027*, TC 0.013*, and fasting insulin 0.003*. A p-value of less than 0.05 is regarded statistically significant (*). The range denotes the minimum and maximum values.

3.4. Correlation Between Body Mass Index (BMI) and Fasting Blood Glucose, Lipid Profile, Fasting Insulin, and Metabolic Indices in Cases and Controls.

The comparative study of metabolic factors shows that there were no statistically significant differences found in the Atherogenic Index (AIP), though its value was slightly higher in cases (0.463 compared to 0.403) (p=0.300) (Table 4). Thus, there was no marked variation in the overall atherogenic risk among the groups. In comparison, the TyG index was significantly higher among the cases (4.71 vs. 4.57; p=0.014). This implies possible early dysfunctionality within the glucose-lipid metabolism. Moreover, the HOMA-IR values were significantly higher among the cases (3.17 vs. 2.02; p=0.002). This further suggests the existence of significant insulin resistance.

Table 4: Evaluation Of Atherogenic And Insulin Resistance Markers In Case And Control Participants.

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value
Atherogenic Index (AIP)	0.463 ± 0.21	0.403 ± 0.26	0.300
Range	0.023–1.0	0.15–1.0	
TyG Index	4.71 ± 0.21	4.57 ± 0.30	0.014*
Range	4.3–5.3	3.9–5.2	
HOMA-IR	3.17 ± 3.30	2.02 ± 1.73	0.002*
Range	0.34–18.09	0.68–9.03	

*Values are presented as Mean ± SD. *p*-values for comparison (cases vs controls): AIP 0.300, TyG index 0.014*, and HOMA-IR 0.002*. An asterisk (*) indicates statistical significance (*p* < 0.05). The range denotes the minimum and maximum values. AIP is the Atherogenic Index of Plasma; TyG signifies the Triglyceride–Glucose Index; HOMA-IR represents the Homeostatic Model Assessment of Insulin Resistance.

3.5. Correlation Analysis Between TyG Index, HOMA-IR, and Atherogenic Index of Plasma (AIP) in Cases and Controls.

The correlations and ROC analyses provide different associations between the studied indices and insulin resistance, as well as excellent predictive properties (Table 5). In cases, there was a statistically significant positive correlation between the TyG index and HOMA-IR (r = 0.383, p = 0.015), which is consistent with the notion that the TyG index is a marker of insulin resistance, while AIP does not have a statistically significant correlation (r = 0.242, p = 0.132). On the contrary, in controls, there was a statistically significant correlation between AIP and HOMA-IR (r = 0.342, p = 0.031), but no significant correlation between the TyG index and HOMA-IR (r = 0.242, p = 0.133). Thus, AIP may indicate different metabolic states in various populations. Nevertheless, both indices had high discriminatory values, which may be influenced by sample size according to ROC analysis (AUC = 1.00 for the TyG index and AIP); nevertheless, these results can be biased by the limited number of participants (Figure 1).

Table 5: Associations Between Tyg Index And Homa-Ir, And Homa-Ir And Aip In Cases And Controls.

	Cases		Control	
	Pearson coefficient	**P value**	**Pearson coefficient**	**P value**
TyG index with HOMA-IR	0.383	0.015	0.242	0.133
HOMA-IR with AIP	0.242	0.132	0.342	0.031

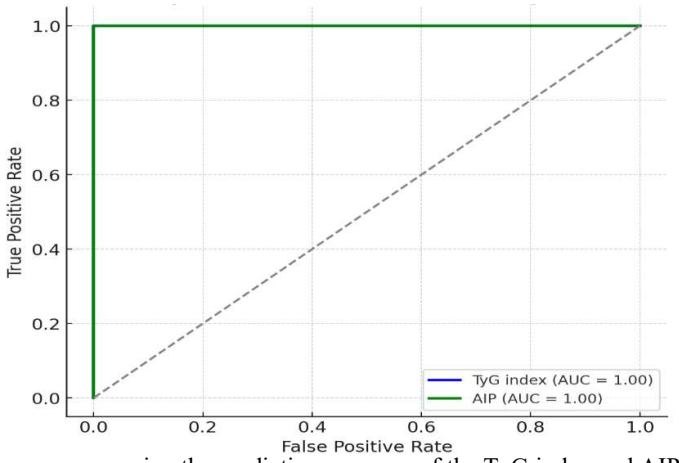

Figure 1: ROC curves comparing the predictive accuracy of the TyG index and AIP for insulin resistance.

3. DISCUSSION

The prevalence of childhood obesity is linked to the development of insulin resistance, which is not confined only to those with overt disease but could also affect apparently healthy individuals[16]. Several biomarkers, including the AIP and TyG index, have been reported as potential tools for assessing insulin resistance, which are inexpensive and easy to measure[17]. Results from the current study indicate that these biomarkers could be useful as predictors of metabolic dysfunction.

In the current case–control study, while no significant demographic differences have been reported between the two groups, there have been notable differences in terms of physical activity, anthropometric data, and metabolism. The higher prevalence of 8-10-year-olds as well as the balanced gender distribution in both groups can be compared to those identified by Kalyoncu et al. (2025) and Dundar et al. (2023). This similarity shows that the risk of metabolic disorders emerges in middle childhood regardless of gender[18,19]. Moreover, the lack of any demographic difference is like the findings of Katzmarzyk et al. (2019). As a result, the noted differences in metabolic variables likely have a physiological rather than demographic nature[20]. Lower levels of physical activity, as well as the higher prevalence of those who engage in such activity infrequently (30% versus 15%), is like those described by Mark et al. (2008)[21]. Though Zhang et al. (2023) have found an increased correlation, the current lower correlation suggests that physical activity can affect the health risk profile of children[22].

Anthropometric evaluation revealed significantly elevated levels of body mass and BMI in cases compared to controls, whereas the height was similar. The data collected during the current investigation corroborated previous research results reported by El-Aghbary et al. (2023). They pointed to BMI as a reliable indicator of metabolic risks in children[23].

Similarly, Santoro N et al. (2013) found a significant increase in the BMI value (~5 kg/m²) in the study participants[24]. However, BMI did not correlate with the metabolic parameters of the study subjects, which indicates that the BMI value itself could not be an effective predictor of metabolic dysfunction in such a case. It is in line with Wu et al. (2024), who have found a significant increase in metabolic risks associated with childhood obesity with the same BMI (~25) values[25]. Contrary to the results obtained by De Lorenzo et al. (2013), there were no distinct groupings of metabolic risks based on different BMI ranges in the study sample size[26]. The absence of variation in blood pressure levels agrees with Stępniewska et al. (2022)[27].

In this study, the biochemical examination revealed increased fasting blood glucose, triglycerides, total cholesterol, LDL, and VLDL levels among the cases. This observation is supported by the works of Hassan et al. (2023), who identified the association between metabolic disorders, as well as Telles et al. (2018), who conducted their research on children[28,29]. The consistent quantitative increases across multiple measurements indicate a pattern of metabolic dysregulation at the group level rather than isolated anomalies in specific parameters.

The increased triglycerides and LDL found in the current research were supported by previous results from Zheng et al. (2025), where a strong link between lipid abnormalities in childhood and higher risk of cardiovascular disease was established [30]. Furthermore, the insignificant changes in HDL level in this work were inconsistent with reports from Radetti G et al. (2022), where decreased HDL was

highlighted as an important feature of pediatric metabolic syndrome[31]. It could be concluded from such an observation that dyslipidemia in this group is associated with high levels of triglycerides and LDL, not altered HDL levels.

The prominent observations from this study are the markedly high fasting insulin concentrations and insulin resistance indices (TyG index and HOMA-IR) in cases. This finding shows a modest positive correlation with the earlier findings by Tahapary et al. (2023) that HOMA-IR is a dependable indicator of insulin resistance and by Khan et al. (2018) on the validation of the TyG index as an indirect measure[32],[33]. The ability to detect insulin resistance at an early stage in children with metabolic alterations but without symptoms was confirmed by studies by Acikan et al. (2026), [34]. The significantly elevated TyG index observed in cases in this study corroborates the findings by Kalyoncu et al. (2025) that the TyG was found to have an insignificant relationship with insulin resistance and could be used as a surrogate marker for insulin resistance in this population[35]. On the other hand, the AIP was inconsistently associated with insulin resistance in this population. TyG showed a stronger relationship with insulin resistance compared to AIP in this population.

However, remarkably enough, there were no significant correlations observed between the BMI and biochemical parameters in both groups under consideration compared to the results obtained by Faria et al. (2012), according to which the relationship between BMI and metabolism was very high[36]. This difference might have been caused by a relatively small number of participants in the study. Moreover, Narayanan et al. (2026) stated that metabolic disorders do not always depend on BMI in children[37].

The presence of a strong positive correlation between the TyG index and HOMA-IR was found among the patients ($r = 0.383$, $p = 0.015$), which confirms the potential of the TyG index as an indicator of insulin resistance and is in line with the results reported by Mirr et al. (2021)[38]. However, the lack of such a correlation among healthy individuals implies that this association might be apparent in cases of metabolic disturbance. The correlation of HOMA-IR with AIP was found to be significantly positive in controls, but not in cases, a phenomenon also observed by Lin et al. (2018), which suggests that the association of insulin resistance with lipid measures may differ based on metabolic status[39].

In ROC analysis, AUC values of 1.00 were obtained for the TyG index and AIP; thus, theoretically, perfect sensitivity and specificity exist for both indices. Nonetheless, such perfect discriminatory capacity is not common statistically in clinical studies. While ROC analysis provides AUC values of 1.00, these values could be due to small sample sizes (n=40 for each group) or even possible model overfitting instead of actual clinical accuracy; hence, such results must be treated carefully. This issue was pointed out by Navarro-González D et al. (2024), wherein AUC values were not 1.00 but still high[40]. Therefore, these results must be carefully considered, especially since there is a need to validate these results using multiple centers.

Moreover, the findings presented indicate metabolic changes beginning in childhood, especially associated with elevated BMI, dyslipidemia, and indicators of insulin resistance. Decrease physical activity was noted in correlation with these metabolic alterations; however, causation cannot be determined due to the cross-sectional design. Nonetheless, the limited sample size constitutes a significant constraint, hindering generalizability.

4. CONCLUSION

In conclusion, the current study demonstrated a statistically significant correlation between the TyG index and insulin resistance in ostensibly healthy and overweight/obese children and adolescents. Furthermore, the TyG index exhibited a notable association with insulin resistance and may function as a valuable surrogate marker of resistance in these patients. In turn, the research results concerning the AIP did not show a consistent association with insulin resistance in this study, indicating no definite role of the AIP index in detecting insulin resistance in the studied group of people. In general, metabolic alterations could appear in early childhood and adolescence among seemingly healthy individuals, suggesting a propensity to future cardiovascular or academic issues.

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