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ORIGINAL ARTICLE

# Association between the triglyceride glucose index as a measure of insulin resistance and waist-to-hip ratio in apparently healthy students of University of Sarajevo

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## ABSTRACT

**Aim** To reveal the prevalence of the insulin resistance (IR) identified by triglyceride glucose index (TyG index) among students of the University of Sarajevo as well as the impact of visceral fat level (VFL) and waist-to-hip ratio (WHR) on TyG value.

**Methods** The study included 160 apparently healthy students, both genders, aged 19-27 years. Two groups were formed: Group 1, TyG <4.49 and Group 2, TyG≥4.49. A short interview, questionnaire, anthropometric measures, VFL, blood pressure and biochemical parameters were applied.

**Results** Forty-five (28.1%) students were insulin resistant. There was a significant difference in TyG value between the groups: 1- 4.19 (3.93-4.34) vs. 2-4.59 (4.55-4.74) (p<0.001). Fasting blood glucose (FBG) and lipid parameters (total cholesterol, triglycerides, and very low-density lipoprotein cholesterol (TC, TG and VLDL-C) were significantly higher in the TyG ≥4.49 group compared to the TyG <4.49 group, with the exception of HDL-C and LDL-C (p>0.05). Linear regression analysis showed significant impact of waist to hip ratio on TyG value (p=0.001).

**Conclusion** The prevalence of IR measured by TyG in university students was 28.1%. The impact of waist-to-hip ratio on the value of TyG index points on possible application of both parameters in visceral obesity and insulin resistance assessment in apparently healthy individuals.

**Keywords:** blood glucose, triglycerides, obesity, prevalence

## INTRODUCTION

Insulin resistance (IR) is frequent in apparently healthy young individuals in medical practice. The increasing prevalence of deteriorating metabolic control at that age and the trend of its worsening are a matter of real concern. Insulin resistance refers to a failure of insulin dependent tissues to use and metabolize glucose properly (1). An inappropriate insulin regulation of glucose metabolism results in hyperglycaemia, hyperlipidaemia, and obesity over time (2). Manny factors besides diet and life style, such as pubertal increase in the prevalence of insulin resistance and incompetent transition from paediatric to adult care, are associated with deteriorating glycaemic control in youth (3). Since insulin resistance measures have not been fully integrated into clinical guidelines, the clinical presentation implies the presence of insulin resistance (4). The diagnostic criteria for IR are not well defined, which can result in an unsuitable approach (5). Early identification of IR is particularly important due to its association with many metabolic complications such as defective glucose uptake, reduced glycogen synthesis, enhanced lipid oxidation, increased oxidative stress and inflammation associated with glucotoxicity and lipotoxicity (6). Moreover, prevalence of IR increases across the decades from young adulthood onwards, and the risk of adverse cardiovascular outcomes later in life increases (7).

Due to high costs of fasting insulin measurement, there are many attempts to develop surrogate markers that can be used in screening studies in apparently healthy individuals (8). The triglyceride glucose index (TyG index) can serve as an effective alternative biomarker for insulin resistance due to its high sensitivity and specificity, and is considered as a convenient and cost-effective parameter (9). This marker is suggested as a possible independent predictor of an increased risk of subclinical atherosclerosis and arterial stiffness (10).

According to scientific data, adiposity is associated with insulin resistance. Association between obesity, especially visceral obesity, and the TyG index has been investigated in type 2 diabetes mellitus (11), but it is inconclusive in apparently healthy individuals with insulin resistance. Relationship between obesity and insulin resistance is confusing, because IR can be identified in normal body weight individuals (7), but also 10%-40% of obese individuals are metabolically healthy (12).

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TyG index can be applied to identify IR in general population, especially in developing countries (13). Insulin resistance is poorly investigated in Bosnia and Herzegovina in university students who are apparently healthy. Increasing prevalence of obesity, diabetes type 2, menstrual abnormalities and polycystic ovarian syndrome (POCS) in young women using the low-cost and effective parameters, put the early detection of IR in the list of high priorities of primary health care in developing countries. The aim of this study was to investigate the prevalence of the insulin resistance identified by TyG index among apparently healthy students at the University of Sarajevo, as well as the impact of visceral fat level and waist-to-hip ratio (WHR) measures on TyG value.

## EXAMINEES AND METHODS

### Examinees and study design

This cross-sectional study recruited 160 university students, aged between 19-27 years of both genders, during the period between May and December 2024. The study included students of School of Medicine, Dentistry, Pharmacy and Health Studies, who voluntarily applied to participate in the study. University students were informed about the significance of the study through a public presentation and invited to apply for inclusion. Inclusion criteria were apparently healthy students. Exclusion criteria were students with chronic and acute diseases.

Based on TyG index of ≥4.49 used as cut-off value, the students were divided into two groups: Group 1 TyG <4.49 and Group 2 TyG ≥4.49 marked as insulin resistance group.

All participants were informed about the significance of the study and signed an informed consent form.

The Ethics Committee of the Faculty of Medicine, University of Sarajevo, approved the study. The study was conducted in accordance with the Helsinki Declaration (14).

### Methods

Following short in-person interviews, the students were asked to fill out a questionnaire. It included questions about the age, life habits (smoking, alcohol consumption, fast food, dietary diversity, sedentary or active lifestyle), health issues (polycystic ovary syndrome, sudden hunger craving, regular sugar craving) and data related to the family history of diseases such as diabetes mellitus, arterial hypertension, dyslipidaemia, obesity and cardiovascular disease.

Body weight and height were measured while students were wearing light clothing and without shoes. Their height was measured with a portable stadiometer, and weight using an electronic scale. All circumferences were measured using stretch-resistant flexible measuring tape. Subjects were asked to stand upright in a relaxed posture and exhale during waist measurement. Waist and hip circumference measurements were made in accordance with the WHO STEPS surveillance manual (15). Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest. Hip circumference was measured around the widest portion of the buttocks. Neck circumference was measured below the thyroid cartilage, perpendicular to the longitudinal axis of the neck (16). Mid-upper arm circumference was measured at the mid-point between the olecranon and the acromion. Blood pressure measurement was taken utilizing an aneroid sphygmomanometer, while the students were sitting upright.

Fasting blood sample was collected from each participant and used for obtaining serum. Serum level of fasting blood glucose (FBG), total cholesterol (TC), and triglycerides (TG) were measured using enzymatic colorimetric methods. The enzymatic-elimination methods were applied to measure high-density lipoprotein cholesterol (HDL-C) and low density lipoprotein cholesterol (LDL-C) using corresponding kits (Gesan Production s.r.l. Italy), and analyser Gesan Chem 200 (Gesan Production, Italy). Calculations included body mass index (BMI; kg/m$^2$) (17), VFL determined through bioelectrical impedance analysis using an InBody 270 body composition analyser (InBody USA) (18), and TyG index= logarithm (triglycerides) (mmol/L) × glucose level (mg/d L)/2) (13). Waist-to-hip ratio was calculated as well.

### Statistical analysis

All variables were tested for normal distribution using the Kolmogorof-Smirnov test. Descriptive statistics was used to summarize the baseline characteristics of the students. Categorical variables were presented in term of number (N) and percentage (%). The frequencies of categorical variables were compared using a $\chi 2$ test with continuity correction for 2x2 tables. Depending on data normality, numerical variables were presented by median with 25$^{th}$-75$^{th}$ percentile or mean±standard deviation (SD). Comparison between the groups was done by Mann-Whitney U test or independent t-test. Linear regression analysis was done to test the impact of VFL, WHR and HDL-C in students with TyG value marked as insulin resistance. For all tests the significance was set at $p<0.05$.

## RESULTS

The study included 160 students - median age was 20 years with the range 19-24 years (Table 1). According to data obtained by questionnaire, healthy lifestyle was predominant (Table 1). Higher frequencies of non-smoking vs smoking, non-consuming alcohol vs consuming alcohol, non-consuming fast- food vs consuming fast food, and dietary diversity among the participants vs monotonous diet were found.

**Table. 1. Basic characteristics of 160 university students**

| Variable | No (%) of students in the group | |
|---|---|---|
| | NO | YES |
| Smoking | 119 (74.4) | 41 (25.6) |
| Alcohol | 146 (91.3) | 14 (8.8) |
| Dietary diversity | 26 (16.3) | 134 (83.8) |
| Fast food | 93 (58.1) | 67 (41.9) |
| Regular sugar craving | 38 (23.8) | 122 (76.3) |
| Sudden hunger craving | 102 (63.7) | 58 (36.3) |
| Life style, sedentary | 91 (56.9) | 69 (43.1) |
| Polycystic ovary syndrome | 147 (91.9) | 13 (8.1) |
| Insulin resistance (TyG index ≥4.49) | 115 (71.8) | 45 (28.1) |
| **Family history** | | |
| CVD | 109 (68.1) | 51 (31.9) |
| HTA | 79 (49.4) | 81 (50.6) |
| DM | 102 (63.7) | 58 (36.3) |
| Dyslipidaemia | 141 (88.1) | 19 (11.9) |
| Obesity | 121 (75.6) | 39 (24.4) |

CVD, cardiovascular disease; HTA, arterial hypertension; DM, diabetes mellitus; TyG index, triglycerides glucose index;

An active life style was noted in 91 (56.9%) students. TyG index value of ≥4.49 was found in 45 (28.1%) among 160 tested students. According to the questionnaire data, polycystic ovary syndrome (PCOS) was already diagnosed in 13 out of 134 female students (9,7%). According to the cut-off value of TyG 4.49 for IR, the participants were distributed into two groups: Group 1 TyG <4.49 [median 4.19 (3.93-4.34)] and Group 2 TyG≥4.49 [median 4.59 (4.55-4.74]; p<0.001. Out of 134 female participants, 13 (9.7%) had previously diagnosed POCS but only two (1.49 %) had TyG ≥4.49. A significant association between TyG index value and POCS was not found (p=0.355). Significant differences in gender distribution and participants' age between the two groups (p>0.005) were not found (Table 2).

**Table 2. TyG index value-based gender and age distribution of the students**

| Variable | | Group 1 (TyG <4.49) (N =115) | | Group 2 (TyG≥4.49) (N=45) | | p |
|---|---|---|---|---|---|---|
| **Gender** (N, %) | M | 16 | (13.91) | 10 | (22.22) | 0.235 |
| | F | 99 | (86.08) | 35 | (77.77) | |
| **Age** (year) Med ($25^{th}$-$75^{th}$) | | 20 (20-21) | | 20 (20-21) | | 0.549 |

M, male; F, female; N, number of participants; %, percentage; TyG, triglycerides-glucose index; Med ($25^{th}$-$75^{th}$) median with range between $25^{th}$ and $75^{th}$ percentile;

Median FBG and lipid parameters were significantly higher in Group 2 excluding HDL-C and LDL-C (p>0.05). Fifty-four (33.7%) participants had HDL-C <1 mmoL, but it was not associated significantly with insulin resistance (p=0.576) (Table 3).

**Table 3. Blood glucose level and lipid parameter values analysis based on students' TyG index value**

| Variable | Median ($25^{th}$-$75^{th}$ percentile) Group 1 (TyG <4.49) (N=115) | Median ($25^{th}$-$75^{th}$ percentile) Group 2 (TyG ≥4.49) (N=45) | p |
|---|---|---|---|
| FBG (mmol/ L) | 4.1 (3.40-4.60) | 4.3 (3.70-4.90) | 0.024 |
| TC (mmol/ L) | 2.93(1.99-3.66) | 3.55(2.82-3.97) | 0.022 |
| TG (mmol/ L) | 0.71(0.47-0.87) | 1.55(1.29-1.95) | <0.001 |
| VLDL-C (mmol/ L) | 0.32(0.22-0.39) | 0.71(0.58-0.89) | <0.001 |
| LDL-C (mmol/ L) | 1.20(0.95-1.62) | 1.47(0.96-1.85) | 0.164 |
| HDL-C (mmol/L) | 1.21(0.95-1.46) | 1.28(0.97-1.50) | 0.566 |

FBG, fasting blood glucose; TC, total cholesterol; TG, triglycerides, VLDL-C, very low density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; HDL-C, high density lipoprotein cholesterol; p value, probability;

Median values of anthropometric measures were in the physiological range and there were no differences in parameters between the groups (p>0.05). Bioelectrical impedance analysis of VFL showed that 53 (33.1%) participants had VFL ≥10. No significant association between participants' VFL≥10 and insulin resistance prevalence was found (p=0.557), however, association between VFL≥10 and HDL-C below 1 mmol/L was found (p=0.032 (Table 3).

Regression model from a set of candidate predictor variables such as VFL, HDL-C <1 mmol/L, and WHR for predicting the value of TyG index revealed that only WHR had an impact on TyG value (p=0.001) (Table 5).

**Table 4. Anthropometric measures, visceral fat level and blood pressure analysis based on students' TyG index value**

| Variable | Group 1 (TyG <4.49) (N=115) | Group 2 (TyG ≥4.49) (N=45) | p |
|---|---|---|---|
| Hip circumference (cm) (mean±SD) | 97.61±9.5 | 99.33±12.62 | 0.413 |
| | **Median ($25^{th}$-$75^{th}$ percentile)** | | |
| Body mass index (kg/m2) | 23.20 (21.40-25.30) | 23.4 (20.95-28.15) | 0.315 |
| Waist circumference (cm) | 74 (69-80) | 77 (69.5-86) | 0.151 |
| Waist to hip ratio (cm) | 0.77 (0.74-0.81) | 0.78 (0.74-0.83) | 0.165 |
| Neck circumference (cm) | 33 (31-35) | 33 (31-37) | 0.592 |
| Mid-Upper arm circumference (cm) | 27 (25-30) | 27 (24-30) | 0.706 |
| Visceral fat level | 8 (5-10) | 7 (5-13) | 0.821 |
| Systolic blood pressure (mmHg) | 120 (115-120) | 120 (110-130) | 0.912 |
| Diastolic blood pressure (mmHg) | 80 (70-80) | 80 (75-80) | 0.192 |

SD, standard deviation;

**Table 5. Linear regression analysis between triglycerides-glucose (TyG) index as dependent and waist-to-hip (WHR) ratio as independent variable**

| Variable | Unstandardized coefficient B | Unstandardized coefficient SE B | Standardized coefficient β | t | p | 95% CI for B Lower bound | 95% CI for B Upper bound |
|---|---|---|---|---|---|---|---|
| Waist-to-hip ratio (cm) | 1.709 | 0.516 | 0.255 | 3.313 | 0.001 | 0.690 | 2.728 |
| Dependant variable: TyG index | | | | | | | |

B, unstandardized beta; SE B, standard error for unstandardized beta; β, standardized beta; CI, confidence interval for B;

According to the unstandardized coefficient B, each increase in hip-waist ratio for 1 increases the TyG value for 1.70 (CI for B 0.69-2.7).

## DISCUSSION

The TyG index is suitable for daily clinical practice since it is easy to measure and calculate from routinely available laboratory variables. That leads to early identification of people at high risk of cardiometabolic complications (19). Regarding basic characteristics of the university students included in the study obtained by a short interview and filling out the questionnaire, it was discovered that more participants showed healthy life style. Using recommended cut-off value of ≥4.49 for TyG index as an alternative for Homeostasis Model Assessment (HOMA-IR) (20), the present study found 28.1% insulin resistant participants. It is known that IR is prevalent among university students, which is mainly detected by HOMA-IR; HOMA-IR and the TyG index are widely used methods for determining IR; however, the usage of TyG index is reasonable for low-income countries due to high cost of insulin measurement (21). Evaluation of TyG index showed 99% specificity of HOMA-IR and considered as a valuable surrogate marker of IR (22, 23).

The prevalence of IR detected in our study was within the range 7-40%, which is similar to other studies (19, 24-27). According to the literature data, IR is associated with 13.5% females and urban residency 17.0% (25). In our study more females than males were applied for the study, so gender distribution was not significantly different between the TyG <4.49 and TyG≥4.49 groups. The prevalence of IR is higher in medical students (26, 27).

Fasting blood glucose and lipid parameters with the exception of LDL and HDL were significantly lower in the study group TyG<4.49 indicating better metabolic regulation. Insulin resistance contributes to dyslipidaemia due to the increase of VLDL synthesis and accelerated HDL clearance leading to HDL reduction (28). More than 1/3 of participants (33.7%) in our study had HDL-C <1 mmol/L. All anthropometric indices in the study groups were within the recommended range and no difference between the groups was found.

The TyG index is considered as the superior marker over visceral adiposity indicators and lipid parameters for insulin resistance detection (29). Recently, it was found that the presence of metabolic disease in normal-weight individuals is common, indicating the significance of visceral fat level over BMI (30). Among anthropometric indices, we have proven WHR, as reflective measure of visceral fat had a predictive value on TyG index and was superior over VFL measured by bioimpedance. It was in concordance with the study finding that the WHR influences HOMA-IR both directly and indirectly through the TyG index and that the intensity of the WHR influence on the TyG index is more manifested in girls (31).

Insulin resistance and the TyG index value are related due to metabolic disturbances that cause increased transport of free fatty acids to the liver, impairment of muscle glucose metabolism, promotion of triglycerides synthesis, inhibition of lipolysis and stimulation of lipoprotein lipase activity (32). There is a concern about the increasing prevalence of those with normal BMI, but with excessive visceral fat. Insulin resistance is associated with obesity due to lipolytic effects of adipocytes leading to large amounts of free fatty acids, impaired secretion of adipokines, both being involved in the modulation of insulin sensitivity (33).

Increasing prevalence of IR in young people requires the integration of novel marker of IR in everyday practice in order to implement preventive actions, especially in young, non-obese apparently healthy people and to reverse increasing tendency of IR among young people.

In conclusion, due to the scarcity of studies that addressed prevalence of IR among university students in our country, this study provided an important attempt to highlight the clinical significance of the TyG index as a low-cost marker for IR. Although well-known risk factors associated with insulin resistance were not found within this population of university students, insulin resistant students were found. Predictive power of waist-to-hip ratio for TyG index points to the influence of waist-to-hip ratio on insulin resistance via TyG index.

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## TRANSPARENCY DECLARATION

Conflict of interest: None to declare.

## AUTHOR CONTRIBUTIONS STATEMENT:

Conceptualization, article writing S.H.; methodology, R. J., E. K., A. T., L. M. and A. Đ.; software, S. H.; critical review R. J., E. K, S. H. and A. Đ.

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