International Journal of General Medicine

Dovepress
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ORIGINAL RESEARCH

Triglyceride–Glucose Index (TyG Index) in Association with Blood Pressure in Adults: A Retrospective Study

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Background: High blood pressure (BP) is a major risk factor for cardiovascular disease. The triglyceride-glucose (TyG) index is a useful tool for identifying insulin resistance at an early stage and has been proposed as a cost-effective predictor for hypertension. However, available studies are limited. This study aims to investigate the association between the TyG index and BP.

Methods: Retrospective hospital data of a large cohort (n=1596) of adults aged ≥18 in Saudi Arabia were analyzed. The TyG index was calculated. Lipid markers, systolic BP (SBP), diastolic BP (DBP), and body mass index (BMI) were included.

Results: Across quartiles of the TyG index, SBP was significantly higher in those with higher vs lower TyG ($p<0.03$). No significant association was observed for DBP. A 2-SD higher SBP was significantly associated with a TyG difference of 1.7 (95% CI: 0.1, 3.3). In subgroup analysis, the relationship prevailed in females only [1.8 (95% CI: 0.3, 3.3)]. Across BMI categories (normal, overweight, obesity), the association between SBP and TyG was observed in participants with obesity only.

Conclusions: The TyG index may act as a cost-effective predictive marker for high blood pressure, especially among specific subgroups. Future prospective studies are needed to confirm this relationship.

Keywords: triglyceride-glucose index, blood pressure, hypertension, hyperlipidemia, cardiovascular disease

Introduction

High blood pressure is a major risk factor for cardiovascular disease, a leading cause of mortality worldwide, contributing to over 17 million deaths a year.[1] The estimated global prevalence of hypertension based on 2010 data was 31.1% worldwide, varying geographically.[2] A recent study that collected representative data as part of the national survey in Saudi Arabia estimated the prevalence of hypertension among those ≥15 years to be 9.2% overall, with higher rates among women and older adults.[3] The burden of high blood pressure in Saudi Arabia contributes to the over 200,000 people with cardiovascular disease in the country as of 2016.[4] Addressing the burden of hypertension is essential from a health and economic perspective.[4] Unfortunately, mitigating the impact is complicated by the fact that many people with hypertension remain undiagnosed,[5] highlighting the need for effective and efficient methods for identifying those at risk to improve risk stratification and therapy.

The triglyceride-glucose (TyG) index is a surrogate marker of insulin resistance.[6] It is an inexpensive test calculated from the commonly available measures of fasting triglyceride and fasting plasma glucose levels.[6] For the original intended purpose of identifying individuals with insulin resistance, the TyG index showed high sensitivity, making it a valuable tool for early risk identification, and improving cost-effectiveness in case finding.[6] Since then, the TyG index has been examined for its prognostic or predictive capabilities for other outcomes,[7,8] including hypertension.[9–16] In 2021, Wang and et al conducted a meta-analysis of eight observational studies that showed an adjusted risk ratio of 1.53 (95%

Received: 6 June 2024
Accepted: 30 July 2024
Published: 6 August 2024

CI: 1.26–1.85) for hypertension among adults with the highest vs lowest TyG index.[10] In 2023, a systematic review and meta-analysis of 22 observational studies conducted in China found that an elevated TyG index was associated with a 1.36 (95% CI: 1.28–1.45) odds of developing hypertension with a linear trend.[11] There have also been several studies since the meta-analysis in 2021 from Korea, Japan, Mexico, Singapore, and Thailand echoing the positive relationship between the TyG index and blood pressure or hypertension.[12–16] Regarding studies on TyG conducted in Saudi Arabia, evidence is limited.

A prospective cohort study examining the TyG index in relation to mortality and cardiovascular disease across 22 countries, which included Saudi Arabia, found that participants with a higher TyG index had a higher prevalence of hypertension and higher systolic and diastolic blood pressure in unadjusted baseline characteristic analyses combined for all countries.[7] To our knowledge, no other study has examined the relationship between the TyG index and blood pressure in Saudi Arabia and none have published adjusted and subgroup analyses for this population. This retrospective cohort study aimed to examine the association between the TyG index and blood pressure among adults in Saudi Arabia.

Materials and Methods

Study Design

Clinical and other data were collected retrospectively from the patients' registry at the Prince Sultan Military Medical City. Records between 2022 and 2023 of a total of 4732 patients >18 years of age were initially reviewed. A total of 3136 patients with missing fasting triglycerides and glucose readings were excluded; therefore, this study included 1596 adults (740 men and 856 women). This study was approved by the Institutional Review Board at Prince Sultan Military Medical City (IRB number E-2115) and complies with the Declaration of Helsinki.

Biomarkers

Fasting blood samples (8–10 hr) are routinely collected from patients and transported to the laboratory for biochemical analysis. Readings are then recorded in patient files. Regular quality assurance and control measures were implemented for all laboratory equipment according to protocol. Fasting glucose and fasting triglycerides levels were measured utilizing Cobas-8000 autoanalyzer (Roche Diagnostics, Switzerland) applying the enzymatic reference method with hexokinase (Roche, Cas No: 8717).

For other biochemical data, including platelet count and differential white cell count (neutrophils, lymphocytes, monocytes), a hematology analyzer Sysmex XN analyzer (Sysmex©, Japan) was used for analysis following the instruction manual. To calculate the Triglyceride Glucose Index (TyG index), the following formula was applied.[17]

$$\text{TyG index} = \text{Ln}\frac{\text{fasting triglyceride}\left(\frac{\text{mg}}{\text{dL}}\right) \times \text{fasting glucose}\left(\frac{\text{mg}}{\text{dL}}\right)}{2}$$

Type 2 Diabetes is defined as having a fasting blood glucose level of less than 100 mg/dL, or a 2-hour plasma glucose tolerance test of less than 140 mg/dL, or a hemoglobin A1c (HbA1c) level of 5.6% (38 mmol/mol) or less. Prediabetes is diagnosed when the blood glucose level is higher than normal but not high enough to be considered diabetes. This is reported when the fasting blood glucose level is between 100 mg/dL and 125 mg/dL, or when a 2-hour plasma glucose tolerance test is between 140 mg/dL and 199 mg/dL, or when the HbA1c level is between 5.7% to 6.4% (39 mmol/mol to 46 mmol/mol). Diabetes is diagnosed when the fasting blood glucose level is 126 mg/dL or higher, or when a 2-hour plasma glucose tolerance test is 200 mg/dL or higher, or when the HbA1c level is 6.5% (48 mmol/mol) or higher, confirmed by a repeated test on a different day.

Blood Pressure and Anthropometric Data

Blood pressure was measured in a quiet room with patients sitting and their feet on the floor and after emptying their bladder. Trained staff recorded readings twice using (Omron HEM 705-CP, OMRON Corp., Kyoto, Japan). If a patient had more than one blood pressure measurement, the average of all measurements was taken into consideration. A systolic blood pressure (SBP) ≥130 mmHg or diastolic blood pressure (DBP) ≥80 mmHg[18] indicates hypertension.

Weight and height were measured using a weighing scale and a portable stadiometer (Marsden H226), and patients were asked to remove shoes and heavy clothing. To calculate body mass index (BMI), the weight (kg) was divided by body height (m^2). BMI was divided into normal if BMI ≤25.0 kg/m^2, overweight if BMI >25.0 and ≤ 30.0 kg/m^2, and obese if BMI >30.0 kg/m^2.

Statistical Analysis

Characteristics of participants are presented as means (standard deviations (SD)) for continuous variables and percentages for categorical variables.

Linear regression (applied using the PROC GLM function in SAS 9.3) was used to calculate age and gender-adjusted means of characteristics by quartiles of TyG index (Q1 <3.9, Q2 ≥3.9 to < 6.1, Q3 ≥ 6.1 to < 9.7, Q4 ≥ 9.7).

Linear regression analysis adjusted for factors that could confound the association between TyG index and high BP was used to identify associations between TyG and 2 SD higher SBP (39.1 mmHg) and DBP (22.1 mmHg). Model 1 was adjusted for age and gender. Model 2 is model 1, additionally adjusted for BMI and the presence of high blood pressure. No potential effect modification by gender, BMI, and age was detected using interaction terms.

We repeated the regression analysis in subgroups stratified analyses by gender, BMI groups, presence of hypertension (hypertensive/non-hypertensive), diabetes status (diabetic/prediabetic/non-diabetic), and age groups (into ≤ 24.0 y, 24.1–54.0 y, 54.1–64.0 y, ≥ 64.1 y)[19] was done. A p-value <0.05 was considered statistically significant. SAS version 9.3 by SAS Institute in Cary, NC, USA, was used for all statistical analyses.

Results

Baseline Characteristics

A total of 1596 participants were identified for this analysis (740 men and 856 women). The average age (SD) was 48.6 (±18.6) years (Table 1). About 32.9% were non-diabetic, 42.1% prediabetic, and 25.0% were diabetic. Of the participants, 76.0% had normal weight, 10.0% were overweight, and 14% were obese. The average SBP/DBP was 126.3 (19.5)/

Table 1 Baseline Characteristics, n=1596[a]

Variables	Mean (SD) or %	
Age (y)	48.6	(18.6)
Age groups (y)		
≤ 24	11.4	
25–54	48.4	
55–64	20.8	
≥65	19.4	
Male	40.7	
Female	59.3	
BMI (kg/m^2)	29.6	(18.0)
Normal weight	76.0	
Overweight	10.0	
Obese	14.0	
Non-diabetic	32.9	
Prediabetic	42.1	
Diabetic	25.0	
SBP (mmHg)	126.3	(19.5)
DBP (mmHg)	74.4	(11.4)
Hypertension	14.0	
Neutrophil 10^9/L	3.7	(1.8)
Platelet 10^9/L	298.9	(84.1)
Lymphocyte 10^9/L	2.5	(0.9)

(*Continued*)

Table 1 (Continued).

Variables	Mean (SD) or %	
White Blood Cells 10^9/L	7.0	(2.4)
FBS (mg/dL)	131.6	(58.9)
Insulin (pmol/L)	14.8	(11.6)
HBA1C %	6.7	(1.8)
Cholesterol (mg/dL)	176.4	(43.1)
Triglycerides (mg/dL)	126.9	(78.9)
Low-density lipoprotein (mg/dL)	103.2	(34.5)
High-density lipoprotein (mg/dL)	48.4	(13.1)
TYG index	6.3	(2.0)

Note: [a]Data are presented as mean (SD) or %.
Abbreviations: BMI, Body mass index; DBP, Diastolic Blood Pressure, FBS, Fasting blood sugar; HBA1C, Hemoglobin A1c; SBP, Systolic Blood Pressure; TyG, triglyceride-glucose.

74.4 (11.4) mmHg. The average triglyceride level was 126.9 (79.8) mg/dL, and the mean FBS was 131.6 (58.9) mg/dL. The mean TyG index was 6.3 (2.0). Around 32.9% of the participants did not have diabetes, 42.1% had prediabetes, and 25.0% were diagnosed with diabetes. The average BMI was 29.6 (8.1) kg/m^2. Among all the participants, 76.0% had normal weight, 10.0% were overweight, and 14% were obese.

Across quartiles of the TyG index, SBP was significantly higher in those with higher than lower TyG ($p<0.03$). No significant association was observed for DBP. Cholesterol, triglycerides, and LDL were all significantly higher in those with high vs low TyG index ($p<0.0001$) (Table 2).

In total participants, two SDs with higher SBP were significantly associated with a TyG difference of 1.7 (95% CI: 0.1, 3.3) (Model 2; Table 3).

Table 2 Stratification by Quartiles of Triglyceride Glucose Index, n=1596[a]

	TyG index <3.9 Mean (95% CI)	≥3.9 to < 6.1 Mean (95% CI)	≥ 6.1 to < 9.7 Mean (95% CI)	≥ 9.7 Mean (95% CI)	P value
n	399	399	399	399	
TyG (median)	3.0	4.9	7.6	14.0	
Age	44.8(43.3, 46.3)	53.3(51.9, 54.8)	56.7(55.2, 58.1)	57.8(56.3, 59.3)	<0.0001
BMI (kg/m^2)	31.9(28.9, 34.8)	30.1(27.1, 33.2)	31.1(28.0, 34.2)	31.5(28.6, 34.5)	0.87
SBP (mmHg)	129.2(126.8, 131.6)	127.7(125.3, 130.2)	130.4(127.9, 132.9)	132.9(130.4, 135.4)	0.03
DBP (mmHg)	76.2(74.6, 77.7)	75.7(74.1, 77.2)	76.3(74.7, 77.9)	76.2(74.6, 77.8)	0.31
FBS (mg/dL)	94.1(89.6, 98.6)	105.5(101.2, 109.7)	134.3(130.0, 138.6)	194.9(190.6, 199.2)	<0.0001
HBA1C %	6.0(5.9, 6.1)	6.4(6.3, 6.5)	7.2(7.1, 7.3)	8.7(8.6, 8.8)	<0.0001
Insulin (pmol/L)	6.6(1.1, 18.4)	14.2(−14.9, 43.3)	42.9(24.2, 61.6)	9.8(−6.1, 25.8)	0.04
Cholestrol (mg/dL)	174.5(172.7, 176.3)	172.7(168.3, 176.7)	175.5(171.4, 179.6)	191.4(187.3, 195.5)	<0.0001
Triglycerides (mg/dL)	117.3(114.2, 120.5)	103.4(96.1, 110.7)	131.1(123.8, 138.5)	198.4(191.0, 205.7)	<0.0001
LDL (mg/dL)	101.8(100.4, 103.2)	101.7(98.4, 104.4)	103.5(100.2, 106.8)	112.1(108.3, 115.4)	<0.0001
HDL (mg/dL)	49.6(49.1, 50.1)	49.1(47.9, 50.3)	46.4(45.3, 47.6)	43.3(42.1, 44.4)	<0.0001
Neutrophil 10^2/L	3.1(2.9, 3.3)	3.3(3.2, 3.5)	3.6(3.4, 3.7)	3.9(3.7, 4.0)	<0.0001
Platelet 10^2/L	291.1(282.9, 299.3)	297.5(289.2, 305.7)	303.0(294.6, 311.4)	307.7(298.9, 316.4)	0.05
Lymphocyte 10^2/L	2.3(2.2, 2.4)	2.6(2.5, 2.6)	2.7(2.6, 2.8)	2.8(2.7, 2.9)	<0.0001
White Blood Cells 109/L	6.3(6.0, 6.6)	6.7(6.4, 6.9)	7.1(6.8, 7.3)	7.5(7.2, 7.7)	<0.0001

Note: [a]Data are presented as mean (95% CI) adjusted for age and gender.
Abbreviations: BMI, Body mass index; DBP, Diastolic Blood Pressure; FBS, Fasting blood sugar; HBA1C, Hemoglobin A1c; HDL, High-density lipoprotein; LDL, Low-density lipoprotein; SBP, Systolic Blood Pressure; TyG, triglyceride-glucose.

Table 3 Estimated Mean Difference in TyG Index Associated with a 2 SD Higher SBP in Total and Subgroups of Saudi Adults, n=1596[a,b]

	TyG index Mean difference (95% CI)
SBP	
Model 1	2.3(0.8, 3.7)
Model 2	1.7(0.1, 3.3)
Subgroup analysis	
Non diabetic	0.1(−1.0, 1.0)
Pre diabetic	−0.1(−1.1, 1.0)
Diabetic	2.2(−2.5, 6.8)
Normal weight	1.5(−0.9, 3.9)
Overweight	1.7(−2.0, 5.5)
Obese	2.3(0.1, 4.6)
Male	1.4(−1.6, 4.4)
Female	1.8(0.3, 3.3)
Age groups (y)	
≤ 24	7.9(−25.0, 40.7)
25–54	2.6(0.8, 4.4)
55–64	1.3(−0.8, 3.4)
≥65	1.1(−2.3, 4.4)

Note: [a]Data are presented as mean (95% CI, confidence intervals). [b]Model 1 is adjusted for age and sex. Model 2 is model 1 adjusted for white blood cell count, platelet count, body mass index, and presence of high blood pressure. 2 SD in SBP (39.1 mmHg).
Abbreviations: SBP, Systolic Blood Pressure; TyG, triglyceride-glucose.

In subgroup analysis, the relationship prevailed in females only 398.2 (95% CI: 76.7, 719.8). In BMI categories, the association between SBP and TyG was observed in participants with obesity 2.3 (95% CI: 0.1, 4.6).

Across age groups, the association prevailed in adults aged 25–55 years 2.6 (95% CI: 0.8, 4.4) (Model 2; Table 3).

There was no significant relation between TyG index and DBP in main analysis or in subgroup analysis (Table 4).

Table 4 Estimated Mean Difference in TyG Associated with a 2 SD Higher DBP in Total and Subgroups of Saudi Adults, n=1596[a,b]

	TyG index Mean difference (95% CI)
DBP	
Model 1	0.1(−1.5, 1.4)
Model 2	−0.2(−1.7, 1.3)
Subgroup analysis	
Non diabetic	0.2(−0.7, 1.0)
Prediabetic	0.1(−1.0, 1.0)
Diabetic	−0.3(−4.4, 3.8)
Normal weight	1.4(−1.0, 3.7)
Overweight	−3.8(−7.2, −0.5)
Obese	0.3(−1.8, 2.3)
Male	−0.6(−3.5, 2.2)
Female	0.2(−1.1, 1.5)

(*Continued*)

Table 4 (Continued).

	TyG index Mean difference (95% CI)
Age groups (y)	
≤ 24	8.6(−16.2, 33.3)
25–54	1.2(−0.5, 2.8)
55–64	0.6(−1.7, 3.0)
≥65	−3.4(−6.2, −0.7)

Notes: [a]Data are presented as mean (95% CI, confidence intervals). [b]Model 1 is adjusted for age and sex. Model 2 is model 1 adjusted for white blood cell count, platelet count, body mass index, and presence of high blood pressure. 2 SD in DBP (22.1 mmHg).
Abbreviations: DBP, Diastolic Blood Pressure; TyG, triglyceride-glucose.

Discussion

To our knowledge, this study was the first to examine the association between the TyG index and blood pressure among adults in Saudi Arabia. This research is timely considering that people are not being efficiently diagnosed with hypertension, many people are undertreated, and many do not reach blood pressure control.[5] An efficient and effective method for identifying individuals at risk for hypertension and its subsequent health complications is needed in light of the numerous people in Saudi Arabia impacted by this burden.[3] The results of our study indicate a significant relationship between the TyG index and systolic blood pressure. This relationship persisted in subgroup analyses among females, older adults, and those with overweight and obesity but was attenuated overall after adjustment for body mass index.

The relationship between the TyG index and blood pressure is biologically plausible, given the interconnected relationship between cardiovascular health and insulin resistance.[20] Insulin resistance has been linked to cardiovascular disease, even among those without diabetes,[20] and this extends to specific risk factors, including hypertension.[21] Via increased inflammation and oxidative stress, insulin resistance, which alters glucose and lipid metabolism, can lead to endothelial dysfunction and high blood pressure.[20] This plausibility and the numerous other studies on this relationship align with the unadjusted results from this study, demonstrating a relationship between the TyG index and systolic blood pressure.[9–16] However, unlike several other studies, the adjustment for body mass index attenuated this relationship, resulting in non-significant findings.[9,10] For instance, the meta-analysis by Wang et al found that the participant characteristics of mean age, proportion of males, mean body mass index, and study quality, and subgroup analyses by study design, age, or sex, did not influence the association of the TyG index and hypertension.[10] Additionally, a longitudinal examination of retired workers in China with almost ten years of follow-up showed that the positive dose-response association between the TyG index and blood pressure persisted after model adjustments for age, sex, body mass index, and others.[9] A study examining the interactive effects of the TyG index and obesity on hypertension risk found that when combined, TyG index and obesity measures were better for predicting hypertension than TyG alone, indicating the importance of accounting for body mass index.[22] The impact of covariates on the final results indicated a need for subgroup analyses. Assessing the value of the TyG index for predicting hypertension in subgroups can also help identify those for which this index could be most effectively applied. Other research has also found differential relationships between the TyG index and hypertension or blood pressure for different subgroups.[9,11–13] Once subdivided by BMI category, it was evident that the relationship between the TyG index and systolic blood pressure was strongest among adults with obesity, and the relationship was present among those with overweight and obesity but not among those with normal weight. This may be because the development of insulin resistance is linked with obesity.[23]

Subgroup analyses also revealed that the relationship prevailed among females and older adults. Other research has also found the association between TyG and hypertension to be more pronounced among older age groups.[11] This also aligns with a study examining the association between the TyG index and new-onset hypertension, concluding that the relationship was present only among women in stratified analyses.[24] Additionally, a meta-analysis from China showed a more pronounced relationship between TyG and hypertension among females.[11] Although females are thought to be at lower risk for cardiovascular events, this may not be the case when it comes to insulin resistance-related outcomes.[25,26] For instance, women with diabetes were shown to be at higher risk of coronary heart disease and stroke than men.[25,26] It is plausible that the age and sex differences are related to the increased risk of hypertension among females post-menopause due to hormonal changes.[27,28] The impact of hypertension among women in Saudi Arabia is particularly important to explore as it is more prevalent among this group, according to national survey data.[3] This is in alignment with the overall cardiovascular disease risk among women in Saudi Arabia, which is thought to be higher due to the sociocultural norms that perpetuate a sedentary lifestyle.[29]

Comparisons of the present results to others should be made considering variations in the population and overall study design. For instance, a meta-analysis examining the TyG index and risk of hypertension from China determined that 63% of heterogeneity between studies was due to study type, region, sample size, data source, and study quality.[11] Further, previous work has shown that while there is an association between the TyG index and cardiovascular disease incidence (ie, mortality, myocardial infarction, stroke, diabetes), this relationship appears to be geographically or at least economically dependent with the relationship persisting only among low- and middle-income countries.[7] Whether such a pattern is present when it comes to hypertension can be examined in future studies.

Strengths of this study include the use of a large cohort of participants that enabled subgroup analyses, the use of physician diagnoses instead of self-reported diagnoses, and the inclusion of medications as a covariate in the models. In terms of limitations, this cohort is a retrospective analysis of patient hospital records and as such, some variables that may relate to the research question (eg, diet, activity level) were not collected. In addition, the study design does not allow for drawing causal inferences or for follow-up. Lastly, the relationships observed in the present study of Saudi Arabian adults may not be generalizable to other groups.

Conclusion

In conclusion, our study found that the TyG index may act as a predictive marker for hypertension, particularly among specific subgroups in Saudi Arabia. Future research can confirm these findings through prospective cohort studies.

Informed Consent Statement

Informed consent was collected from all participants involved in the study.

Acknowledgments

The authors acknowledge the Researchers Supporting Project number (RSPD2024R559), King Saud University, Riyadh, Saudi Arabia.

Disclosure

The authors report no conflicts of interest in this work.

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