

Sex- and Age-Specific Associations of Triglyceride-Glucose Index with Impaired Renal Function: A Cross-Sectional Study

Yi-Hsuan Chen¹, Wen-Cheng Li^{2,3}, Chia-Wei Lu⁴, Yi-Chuan Chen¹

¹Department of Family Medicine, New Taipei Municipal TuCheng Hospital (Built and Operated by Chang Gung Medical Foundation), New Taipei, Taiwan; ²College of Medicine, Chang Gung University, Taoyuan, Taiwan; ³Department of Family Medicine, Chang-Gung Memorial Hospital at Linkou, Taoyuan, Taiwan; ⁴Department of Emergency, Chang-Gung Memorial Hospital at Linkou, Taoyuan, Taiwan

Correspondence: Wen-Cheng Li, Department of Family Medicine, Chang-Gung Memorial Hospital at Linkou, No. 5, Fuxing Street, Guishan District, Taoyuan, 333423, Taiwan, Tel +886975360722, Email win3135@hotmail.com

Purpose: Triglyceride-glucose (TyG) index, a surrogate marker of insulin resistance, has emerged as a potential predictor of cardiovascular and metabolic diseases. However, its relationship with renal function impairment (RFI) and the influence of age and sex remain unclear. This study aimed to investigate the association between the TyG index and RFI in a large Chinese adult population and to evaluate its potential as an independent risk marker across sex and age groups.

Patients and Methods: We conducted a cross-sectional study involving 21,224 adults aged 16–93 years who underwent health examinations at a tertiary hospital in China. Anthropometric and laboratory data were collected. RFI was defined as an estimated glomerular filtration rate of <60 mL/min/1.73 m² or urinary albumin-to-creatinine ratio of ≥ 30 mg/g. Logistic regression models were used to assess the association between TyG index quartiles and RFI after adjusting for confounders.

Results: The overall prevalence of RFI was 23.5% with a higher prevalence observed in men than in women. Higher TyG index quartiles were associated with increased body mass index (BMI), mean arterial pressure (MAP), triglyceride, fasting glucose, and RFI prevalence. After adjustment for BMI and MAP, the TyG index remained significantly associated with RFI only in females aged ≥ 50 years (adjusted odds ratio for Q4 vs Q1: 1.603, 95% confidence interval: 1.313–1.957, $p < 0.001$).

Conclusion: An elevated TyG index was independently associated with RFI in older women. Owing to its simplicity and cost-effectiveness, TyG index may be a useful tool for early screening of renal risk, particularly among postmenopausal women. Nonetheless, longitudinal studies are needed to confirm a causal relationship.

Keywords: triglyceride-glucose index, renal function impairment, insulin resistance, sex difference, postmenopausal women, chronic kidney disease, metabolic health

Introduction

Renal function impairment (RFI) is a growing global public health challenge and is a major contributor to morbidity and mortality. It is estimated that over 800 million individuals (more than 10% of the global population) are affected by RFI.¹ In Taiwan, RFI and end-stage renal disease (ESRD) are particularly burdensome, with Taiwan ranking among the highest incidences of ESRD globally. Regionally, recent data from Asia indicate that the prevalence of chronic kidney disease (CKD) ranges from 7% to 34%, underscoring the urgent need for effective prevention strategies.² Despite its clinical significance, awareness of RFI remains low, with less than 10% of affected individuals in developed countries being aware of their condition.³

The pathophysiology of RFI is multifactorial and closely intertwined with that of metabolic disorders. Diabetes mellitus (DM), hypertension, and dyslipidemia are established contributors to both the development and progression of RFI.^{4,5} Among these, DM has become increasingly prevalent globally and it is estimated that up to 40% of patients with

DM eventually develop renal impairment.⁶ Insulin resistance (IR), a key underlying feature of type 2 DM, is implicated in the initiation and progression of renal dysfunction.⁷

The triglyceride-glucose (TyG) index has emerged as a reliable, noninvasive surrogate marker for IR. It is calculated based on fasting triglyceride and glucose levels and has demonstrated a strong correlation with the euglycemic-hyperinsulinemic clamp, the gold standard method for assessing IR.^{8–10} Beyond its role in assessing IR, the TyG index has been associated with adverse cardiovascular outcomes and shows promise as a predictive marker for macrovascular diseases such as coronary artery disease.¹¹ Furthermore, growing evidence indicates that the TyG index may also reflect the risk of microvascular complications associated with diabetes, including diabetic nephropathy.^{12,13}

Previous studies have explored the association between the TyG index and renal dysfunction, which generally suggests a positive relationship.¹⁴ Our study uniquely contributes to the field by highlighting sex- and age-specific effects, particularly in postmenopausal women, a subgroup that has often been underrepresented in earlier research. However, the exact mechanisms remain unclear, with inflammation and IR hypothesized to be possible mediators of RFI pathogenesis.¹⁵

By incorporating local and global epidemiological data, this study underscores the need to identify early and practical risk markers for RFI, particularly in Asian populations where the burden of CKD is high.

Materials and Methods

Study Design and Population

This cross-sectional study enrolled 21,224 Chinese adults aged 16–93 years who underwent routine health examinations at the Health Examination Center of Xiamen Chang Gung Hospital (XCGH) between 2013 and 2015. A total of 21,224 individuals participated in the study, of whom 11,979 (56.4%) were male and 9,245 (43.6%) were female. The study protocol was approved by the Institutional Review Board of XCGH (approval number: XMCGIRB2022107) and conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Inclusion and Exclusion Criteria

Eligible participants had complete medical records, including past medical history and medication use. Trained nurses collected fasting venous blood samples and administered standardized questionnaires according to standard operating procedures. Participants were required to fast for at least 12 hours prior to examination. Pregnant women were excluded. Health examination data included anthropometric and biochemical measurements: height, weight, waist circumference, blood pressure, total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG), fasting plasma glucose (FPG), estimated glomerular filtration rate (eGFR), and urine albumin-to-creatinine ratio (ACR).

Participants were excluded if they had (Figure 1):

1. Chronic diseases known to affect metabolism, such as thyroid dysfunction or chronic hepatitis;
2. Current use of hypoglycemic agents or corticosteroids known to impact metabolic profiles.

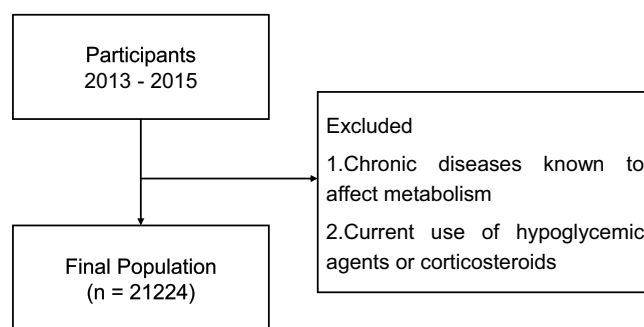


Figure 1 Flow diagram for methodology.

Laboratory Measurements

Fasting plasma glucose was measured using a modified hexokinase enzymatic assay (Cobas Mira Chemistry System; Roche Diagnostics, Montclair, NJ, USA). Serum creatinine, TC, HDL-C, and TG were measured using an automated biochemical analyzer (UniCel® DxC 800 SYNCHRON®, Beckman Coulter, Ireland). Urinary albumin and creatinine concentrations were obtained from fresh spot urine samples using biochemical reagents on the same analyzer. The urine albumin-to-creatinine ratio (ACR) was calculated for each subject.

Anthropometric and Clinical Assessments

Height and weight were measured using calibrated instruments, and body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Waist circumference was measured at the midpoint between the lowest rib and the iliac crest.

Blood pressure was measured on the right arm using an automated sphygmomanometer after the participant had rested for at least 15 minutes in a seated position. Mean arterial pressure (MAP) was calculated using the formula: $MAP = (2/3 \times \text{diastolic pressure}) + (1/3 \times \text{systolic pressure})$.

Definition of Key Variables

TyG index was calculated using the following formula: $TyG \text{ index} = \ln [\text{fasting triglyceride (mg/dL)} \times \text{fasting glucose (mg/dL)} / 2]$.⁸

Definition of eGFR

$eGFR = 175 \times (\text{Serum Creatinine})^{-1.154} \times (\text{Age})^{-0.203} \times (0.742 \text{ only if female})$ ¹⁶

Albuminuria was defined as an ACR ≥ 30 mg/g creatinine.

RFI was defined as either an $eGFR < 60$ mL/min/1.73 m^2 or the presence of albuminuria (ACR ≥ 30 mg/g Cr).¹⁷

Treatment of Missing Data

In our study, no missing data were found for gender status, MAP, or LDL-C. Data on alcohol consumption, smoking status, hypertension, and dyslipidemia were not available in the current dataset. Therefore, no imputation for these variables was required.

Statistical Analysis

Continuous variables were expressed as mean $\pm$ standard deviation (SD), and categorical variables were presented as frequencies (percentages). Between-group differences were assessed using Student's *t*-test for normally distributed continuous variables and the Mann–Whitney *U*-test for non-normally distributed data. The Chi-square test was used for categorical variables. Comparisons across multiple groups were evaluated using one-way analysis of variance (ANOVA), followed by Bonferroni post-hoc correction for pairwise comparisons.

In this study, the TyG index and its related indices (TyG-BMI and TyG-MAP) were analyzed both as continuous variables and as categorical variables divided into quartiles (Q1, Q2, Q3, and Q4). Other potential confounders such as smoking, socioeconomic status, diet, and physical activity were not included, which will be discussed in the limitations section. Univariate and multivariate logistic regression analyses were performed to assess the association between TyG index quartiles and RFI. The results were presented as odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Based on previous research, three models were developed. Model 1 was a preliminary model that does not change any variables. Model 2 was adjusted for body mass index (BMI), while Model 3 further adjusted for mean arterial pressure (MAP), building upon Model 2. The nonlinear relationship of TyG and its correlation indices with RFI was verified using a smooth curve-fitting technique. Subgroup analysis was performed according to age (< 50 , ≥ 50) and sex. All statistical analyses were conducted using the SPSS software (version 25.0; IBM Corp., Armonk, NY, USA). Statistical significance was set at a two-tailed *p*-value < 0.05 .

Results

In total, 21,224 participants were included in the analysis, including 11,979 males (56.4%) and 9245 females (43.6%). The mean age of participants was similar between sexes (46.9 ± 10.5 years in men vs 47.4 ± 10.8 years in women, $p = 0.001$).

Men exhibited significantly higher levels of BMI, waist-to-height ratio (WHtR), MAP, fasting plasma glucose, total cholesterol, triglycerides, LDL-C, and TG/ HDL-C ratio (all $p < 0.001$) (Table 1). In contrast, women had significantly higher HDL-C levels and estimated glomerular filtration rates (eGFRs), indicating better renal function ($p < 0.001$) than men. Notably, the TyG index was significantly higher in the men than in the women. Given the substantial sex differences in the metabolic and renal parameters, all subsequent analyses were stratified by sex.

In men aged < 50 years, increasing TyG index quartiles were significantly associated with higher BMI, WHtR, MAP, fasting glucose, total cholesterol, triglycerides, LDL-C, TG/HDL-C ratio, ACR, prevalence of albuminuria, and RFI (15.8%), along with a progressive decrease in HDL-C levels (all p for trend < 0.001). No consistent trend was observed for the eGFR in this subgroup ($p = 0.417$). Similar associations were observed among men aged ≥ 50 years, although the trend in eGFR remained statistically non-significant but had a higher prevalence of RFI (39.1%), who were most prone to RFI (Table 2).

Among women under 50 years of age, higher TyG index quartiles were similarly associated with unfavorable metabolic profiles, including increased BMI, WHtR, MAP, fasting glucose, total cholesterol, triglycerides, LDL-C, TG/HDL-C ratio, ACR, albuminuria, and a higher prevalence of RFI (4.5%), along with decreased HDL-C levels (all p values for trend < 0.001). Importantly, eGFR showed a significant downward trend across TyG quartiles (p for trend < 0.001), suggesting early renal function decline with a higher prevalence of RFI (24.5%). These patterns were consistent in women aged ≥ 50 years (Table 3).

The association between the TyG index and RFI was further explored using multivariate logistic regression models (Table 4). In Model 1 (unadjusted), TyG index quartiles 3 and 4 were significantly associated with increased odds of RFI in both sex and age groups.

After adjusting for BMI (Model 2), these associations remained significant only in women, particularly in TyG quartiles 3 and 4. Among men, these associations were attenuated and no longer statistically significant.

In Model 3 (Figure 2), which additionally adjusted for BMI and MAP the TyG index remained an independent predictor of RFI only in women aged ≥ 50 years. Specifically, compared with the lowest TyG quartile (Q1 as a reference), the adjusted ORs for RFI were significantly higher in Q3 (OR 1.947; 95% CI: 1.587–2.389; $p < 0.001$) and Q4 (OR 1.603; 95% CI: 1.313–1.957; $p < 0.001$). These findings suggest that TyG index may serve as a sex- and age-specific independent risk factor for RFI, particularly in older women.

Table 1 Main Characteristics of the Study Subjects by Gender

Characteristics	Total	Men	Women	P value
Number	21224	11,979(56.44%)	9245(43.56%)	
Age (year)	47.150 $\pm$ 10.590	46.935 $\pm$ 10.452	47.436 $\pm$ 10.752	0.001
BMI (kg/m ²)	23.890 $\pm$ 3.330	24.551 $\pm$ 3.235	23.026 $\pm$ 3.264	<0.001
Waist-to-height ratio	0.510 $\pm$ 0.060	0.514 $\pm$ 0.051	0.500 $\pm$ 0.060	<0.001
Mean arterial pressure (mmHg)	88.330 $\pm$ 13.370	91.343 $\pm$ 12.698	84.435 $\pm$ 13.201	<0.001
Fasting glucose (mmol/L)	5.400 $\pm$ 1.340	5.504 $\pm$ 1.500	5.270 $\pm$ 1.094	<0.001
Total cholesterol (mmol/L)	5.210 $\pm$ 0.980	5.268 $\pm$ 0.975	5.125 $\pm$ 0.986	<0.001
Triglycerides (mmol/L)	1.510 $\pm$ 1.480	1.791 $\pm$ 1.716	1.141 $\pm$ 0.987	<0.001
LDL- C (mmol/L)	3.290 $\pm$ 0.870	3.396 $\pm$ 0.871	3.159 $\pm$ 0.861	<0.001
HDL- C (mmol/L)	1.290 $\pm$ 0.320	1.191 $\pm$ 0.277	1.427 $\pm$ 0.314	<0.001
TG / HDL-C	1.350 $\pm$ 1.940	1.694 $\pm$ 2.311	0.900 $\pm$ 1.164	<0.001
eGFR (mL/min/1.73 m ²)	100.710 $\pm$ 13.730	98.936 $\pm$ 13.837	102.999 $\pm$ 13.237	<0.001
ACR (mg/g Cr)	13.360 $\pm$ 82.790	12.531 $\pm$ 75.625	14.443 $\pm$ 91.230	0.095
Albuminuria (n, %)	1138 (5.400%)	607 (5.067%)	531 (5.744%)	0.030
RFI (n, %)	4981 (23.500%)	3234 (26.997%)	1747 (18.897%)	<0.001

Notes: The main characteristics of the participants, categorized by sex, are presented in Table 1. p -values are derived from Mann–Whitney U -test (two groups) or Kruskal–Wallis test (four groups).

Abbreviations: BMI, body mass index; MAP, mean arterial pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; ACR, urine albumin-to-creatinine ratio; RFI, renal function impairment.

Table 2 Baseline Characteristics of the Study Subjects According to TyG Index Quartile in Men

Characteristics	TyG Index					
Men<50	Q1	Q2	Q3	Q4	P value	P trend
Number	1902	1903	1903	1903		
Age, years	39.423 ± 6.185	40.570 ± 5.723	40.874 ± 5.458	41.216 ± 5.213	<0.001	<0.001
BMI (kg/m ²)	22.703 ± 3.027	24.422 ± 3.158	25.529 ± 2.988	26.331 ± 2.974	<0.001	<0.001
Waist-to-height ratio	0.479 ± 0.049	0.506 ± 0.048	0.524 ± 0.045	0.537 ± 0.043	<0.001	<0.001
MAP (mmHg)	85.766 ± 10.853	89.098 ± 11.548	92.003 ± 12.332	95.913 ± 12.718	<0.001	<0.001
Fasting glucose (mmol/L)	4.910 ± 0.424	5.094 ± 0.609	5.288 ± 0.863	6.179 ± 2.302	<0.001	<0.001
Total cholesterol (mmol/L)	4.831 ± 0.863	5.165 ± 0.852	5.392 ± 0.917	5.670 ± 1.058	<0.001	<0.001
Triglycerides (mmol/L)	0.768 ± 0.179	1.230 ± 0.175	1.807 ± 0.292	3.729 ± 3.047	<0.001	<0.001
LDL- C (mmol/L)	3.119 ± 0.785	3.488 ± 0.768	3.596 ± 0.842	3.346 ± 0.976	<0.001	<0.001
HDL- C (mmol/L)	1.341 ± 0.298	1.215 ± 0.252	1.140 ± 0.231	1.052 ± 0.200	<0.001	<0.001
TG / HDL-C	0.605 ± 0.205	1.056 ± 0.265	1.653 ± 0.438	3.832 ± 4.340	<0.001	<0.001
eGFR (mL/min/1.73 m ²)	104.315 ± 12.315	102.878 ± 12.344	102.684 ± 12.632	104.038 ± 11.933	<0.001	0.417
ACR (mg/g Cr)	6.307 ± 37.982	7.404 ± 45.617	10.485 ± 73.285	16.783 ± 78.391	<0.001	<0.001
Albuminuria (n, %)	39 (2.100%)	41 (2.200%)	66 (3.500%)	154 (8.100%)	<0.001	<0.001
RFI (n, %)	300 (15.800%)	327 (17.200%)	355 (18.700%)	387 (20.300%)	0.002	<0.001
Men ≥ 50						
Number	1092	1092	1092	1092		
Age, years	59.516 ± 7.349	58.487 ± 6.815	57.392 ± 6.414	57.047 ± 6.380	<0.001	<0.001
BMI (kg/m ²)	22.537 ± 2.897	23.920 ± 2.846	24.882 ± 2.711	25.503 ± 2.842	<0.001	<0.001
Waist-to-height ratio	0.490 ± 0.049	0.516 ± 0.048	0.530 ± 0.044	0.541 ± 0.046	<0.001	<0.001
MAP (mmHg)	88.532 ± 12.823	91.833 ± 12.596	93.284 ± 12.563	96.240 ± 12.977	<0.001	<0.001
Fasting glucose (mmol/L)	5.102 ± 0.610	5.334 ± 0.792	5.657 ± 1.052	6.870 ± 2.691	<0.001	<0.001
Total cholesterol (mmol/L)	4.901 ± 0.905	5.234 ± 0.904	5.397 ± 0.950	5.561 ± 1.011	<0.001	<0.001
Triglycerides (mmol/L)	0.712 ± 0.168	1.138 ± 0.186	1.637 ± 0.299	3.030 ± 1.909	<0.001	<0.001
LDL- C (mmol/L)	3.144 ± 0.807	3.522 ± 0.803	3.609 ± 0.850	3.368 ± 0.985	<0.001	<0.001
HDL- C (mmol/L)	1.366 ± 0.328	1.233 ± 0.253	1.137 ± 0.243	1.061 ± 0.228	<0.001	<0.001
TG / HDL-C	0.554 ± 0.194	0.966 ± 0.267	1.512 ± 0.449	3.097 ± 3.222	<0.001	<0.001
eGFR (mL/min/1.73 m ²)	91.763 ± 12.375	90.886 ± 12.468	90.488 ± 12.482	90.948 ± 13.500	0.122	0.417
ACR (mg/g Cr)	12.442 ± 98.947	12.824 ± 87.255	12.211 ± 34.505	28.578 ± 132.542	<0.001	<0.001
Albuminuria (n, %)	50 (4.600%)	52 (4.800%)	73 (6.700%)	132 (12.100%)	<0.001	<0.001
RFI (n, %)	427 (39.100%)	438 (40.100%)	502 (46.000%)	498 (45.600%)	0.001	<0.001

Notes: The baseline characteristics of men according to metabolic body composition status stratified by age are presented in Table 2. The men participants were classified into two groups: men <50 and ≥50 year-old. *p*-values are derived from Mann–Whitney *U*-test (two groups) or Kruskal–Wallis test (four groups). Due to highly skewed data distribution and presence of outliers, ACR is a commonly skewed indicator. Most individuals have very low values, but a small number may have extremely high values, which can significantly increase the standard deviation. For example, some participants may have very high ACR levels (eg, >300 mg/g Cr). Even if these cases are rare, they can greatly inflate the overall standard deviation.

Abbreviations: BMI, body mass index; MAP, mean arterial pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; ACR, urine albumin-to-creatinine ratio; RFI, renal function impairment.

Table 3 Baseline Characteristics of the Study Subjects According to TyG Index Quartile in Women

Women<50	Q1	Q2	Q3	Q4	P value	P trend
Number	1344	1345	1346	1344		
Age (year)	37.975 ± 6.340	39.558 ± 6.045	40.590 ± 5.927	41.870 ± 5.582	<0.001	<0.001
BMI (kg/m ²)	20.947 ± 2.377	21.461 ± 2.588	22.385 ± 2.864	23.844 ± 3.263	<0.001	<0.001
Waist-to-height ratio	0.455 ± 0.044	0.466 ± 0.046	0.479 ± 0.049	0.504 ± 0.052	<0.001	<0.001
MAP (mmHg)	76.961 ± 9.295	78.216 ± 9.981	80.039 ± 10.619	84.421 ± 12.588	<0.001	<0.001
Fasting glucose (mmol/L)	4.874 ± 0.377	4.921 ± 0.413	5.032 ± 0.434	5.403 ± 1.240	<0.001	<0.001

(Continued)

Table 3 (Continued).

Women<50	Q1	Q2	Q3	Q4	P value	P trend
Total cholesterol (mmol/L)	4.582 ± 0.731	4.715 ± 0.856	4.928 ± 0.795	5.213 ± 1.023	<0.001	<0.001
Triglycerides (mmol/L)	0.455 ± 0.103	0.701 ± 0.084	0.954 ± 0.123	1.776 ± 1.618	<0.001	<0.001
LDL- C (mmol/L)	2.611 ± 0.614	2.844 ± 0.737	3.079 ± 0.713	3.246 ± 0.858	<0.001	<0.001
HDL- C (mmol/L)	1.600 ± 0.320	1.505 ± 0.282	1.431 ± 0.279	1.275 ± 0.269	<0.001	<0.001
TG / HDL-C	0.297 ± 0.094	0.482 ± 0.105	0.693 ± 0.166	1.527 ± 2.228	<0.001	<0.001
eGFR (mL/min/1.73 m ²)	112.663 ± 10.173	109.917 ± 10.399	108.302±10.008	106.945±10.708	<0.001	<0.001
ACR (mg/g Cr)	7.063 ± 11.427	9.396 ± 53.292	9.816 ± 55.783	12.384 ± 49.696	0.030	0.004
Albuminuria (n, %)	28 (2.10%)	32 (2.40%)	39 (2.90%)	60 (4.50%)	0.001	<0.001
RFI (n, %)	62 (4.60%)	83 (6.20%)	97 (7.20%)	149 (11.10%)	<0.001	<0.001
Women ≥ 50						
Number	966	966	968	966		
Age (year)	56.618 ± 5.779	57.855 ± 6.445	58.004 ± 6.285	58.656 ± 6.542	<0.001	<0.001
BMI (kg/m ²)	22.875 ± 3.052	23.939 ± 3.082	24.654 ± 3.078	25.456 ± 3.149	<0.001	<0.001
Waist-to-height ratio	0.508 ± 0.055	0.528 ± 0.054	0.539 ± 0.052	0.556 ± 0.052	<0.001	<0.001
MAP (mmHg)	86.284 ± 12.470	89.983 ± 13.183	91.822 ± 13.419	94.838 ± 12.921	<0.001	<0.001
Fasting glucose (mmol/L)	5.098 ± 0.509	5.249 ± 0.585	5.426 ± 0.714	6.488 ± 2.342	<0.001	<0.001
Total cholesterol (mmol/L)	5.228 ± 0.936	5.456 ± 0.947	5.574 ± 0.993	5.717 ± 1.035	<0.001	<0.001
Triglycerides (mmol/L)	0.641 ± 0.151	1.004 ± 0.138	1.397 ± 0.207	2.468 ± 1.384	<0.001	<0.001
LDL- C (mmol/L)	3.203 ± 0.785	3.514 ± 0.813	3.635 ± 0.888	3.474 ± 0.990	<0.001	<0.001
HDL- C (mmol/L)	1.586 ± 0.329	1.452 ± 0.286	1.329 ± 0.260	1.202 ± 0.233	<0.001	<0.001
TG / HDL-C	0.425 ± 0.144	0.721 ± 0.183	1.093 ± 0.280	2.202 ± 1.591	<0.001	<0.001
eGFR (mL/min/1.73 m ²)	96.271 ± 10.301	93.442 ± 10.924	93.523 ± 11.136	92.820 ± 12.116	<0.001	<0.001
ACR (mg/g Cr)	10.761 ± 29.274	13.313 ± 32.626	20.910 ± 74.009	39.381 ± 244.091	<0.001	<0.001
Albuminuria (n, %)	41 (4.240%)	73 (7.560%)	93 (9.610%)	165 (17.080%)	<0.001	<0.001
RFI (n, %)	237 (24.530%)	349 (36.130%)	350 (36.160%)	420 (43.480%)	<0.001	<0.001

Notes: The baseline characteristics of women according to metabolic body composition status stratified by age are presented in Table 3. The women participants were classified into two groups: women<50 and women≥50 year-old. *p*-values are derived from Mann–Whitney *U*-test (two groups) or Kruskal–Wallis test (four groups). Due to highly skewed data distribution and presence of outliers, ACR is a commonly skewed indicator. Most individuals have very low values, but a small number may have extremely high values, which can significantly increase the standard deviation. For example, some participants may have very high ACR levels (eg, >300 mg/g Cr). Even if these cases are rare, they can greatly inflate the overall standard deviation.

Abbreviations: BMI, body mass index; MAP, mean arterial pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; ACR, urine albumin-to-creatinine ratio; RFI, renal function impairment.

Table 4 Association Between TyG Index and RFI: Multivariable Logistic Regression Analysis

Group	RFI n (%)	Model 1			Model 2			Model 3		
		OR	(95% C.I.)	P value	OR	(95% C.I.)	P value	OR	(95% C.I.)	P value
Men < 50										
TyG index Q1	300 (15.800%)	Reference			Reference			Reference		
TyG index Q2	327 (17.200%)	1.108	0.933 to 1.315	0.241	0.986	0.828 to 1.174	0.873	0.962	0.807 to 1.147	0.668
TyG index Q3	355 (18.700%)	1.225	1.034 to 1.450	0.019	1.013	0.848 to 1.209	0.887	0.962	0.804 to 1.149	0.667
TyG index Q4	387 (20.300%)	1.363	1.154 to 1.610	<0.001	1.069	0.893 to 1.280	0.467	0.965	0.803 to 1.159	0.701
Men ≥ 50										
TyG index Q1	427 (39.100%)	Reference			Reference			Reference		
TyG index Q2	438 (40.100%)	1.043	0.879 to 1.238	0.630	0.948	0.796 to 1.130	0.552	0.930	0.780 to 1.108	0.417
TyG index Q3	502 (46.000%)	1.325	1.118 to 1.571	0.001	1.130	0.946 to 1.350	0.178	1.105	0.925 to 1.321	0.271
TyG index Q4	498 (45.600%)	1.306	1.101 to 1.548	0.002	1.066	0.889 to 1.279	0.490	1.014	0.844 to 1.219	0.881

(Continued)

Table 4 (Continued).

Group	RFI n (%)	Model 1			Model 2			Model 3		
		OR	(95% C.I.)	P value	OR	(95% C.I.)	P value	OR	(95% C.I.)	P value
Women < 50										
TyG index Q1	62 (4.600%)	Reference			Reference			Reference		
TyG index Q2	83 (6.200%)	1.360	0.970 to 1.907	0.075	1.311	0.934 to 1.840	0.117	1.282	0.912 to 1.800	0.152
TyG index Q3	97 (7.200%)	1.606	1.157 to 2.229	0.005	1.450	1.040 to 2.023	0.028	1.380	0.988 to 1.928	0.059
TyG index Q4	149 (11.100%)	2.578	1.898 to 3.503	<0.001	2.104	1.521 to 2.910	<0.001	1.836	1.320 to 2.554	<0.001
Women ≥ 50										
TyG index Q1	237 (24.530%)	Reference			Reference			Reference		
TyG index Q2	349 (36.130%)	1.742	1.431 to 2.121	<0.001	1.641	1.343 to 2.005	<0.001	1.531	1.251 to 1.874	<0.001
TyG index Q3	350 (36.160%)	2.366	1.949 to 2.873	<0.001	2.171	1.775 to 2.655	<0.001	1.947	1.587 to 2.389	<0.001
TyG index Q4	420 (43.480%)	1.740	1.429 to 2.118	<0.001	1.680	1.378 to 2.048	<0.001	1.603	1.313 to 1.957	<0.001

Notes: Model definitions are: Model 1, unadjusted analysis; Model 2, adjusted for BMI; Model 3, Model 2 + mean arterial pressure (MAP). Q1 as reference, compared with Q2-Q4.

Abbreviations: OR, odds ratio; CI, confidence interval.

Discussion

In this cross-sectional study of 21,224 Chinese adults, we included a larger sample size compared to previous studies. The overall prevalence of RFI was 23.5% and the percentage of RFI was higher in men than in women. We found that a higher TyG index was significantly associated with an increased risk of RFI, particularly among women aged ≥50 years. This study had unique subgroup analyses and findings in postmenopausal women. Even after adjusting for confounding factors, including BMI and MAP, the association remained statistically significant, identifying TyG index as an independent risk factor for RFI in this subgroup. These findings suggest that older women with elevated TyG

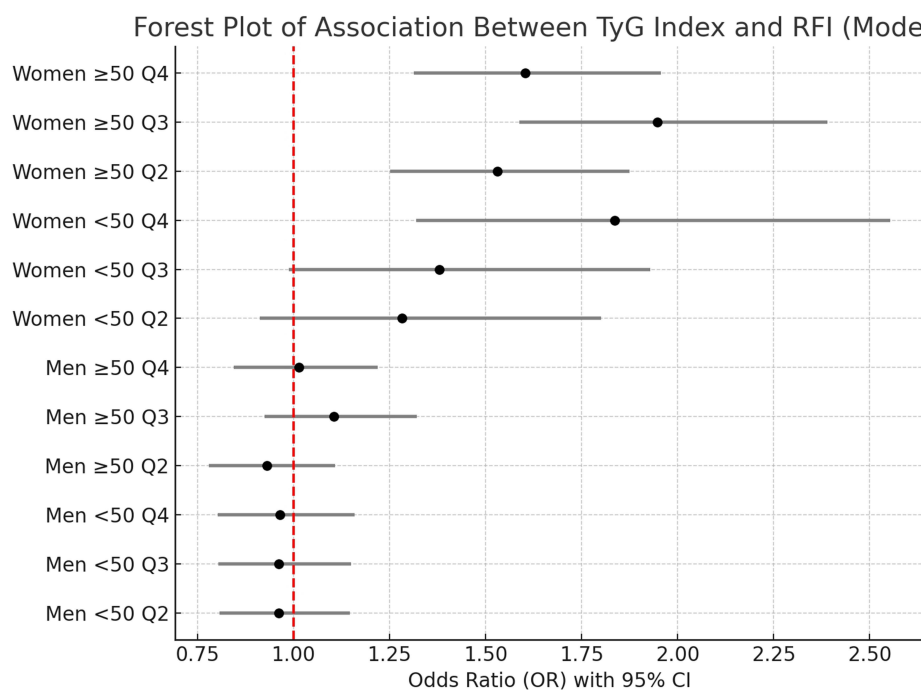


Figure 2 Forest Plot of Association Between TyG Index and RFI (Model 3). Forest plot generated from Table 4 logistic regression results (Model 3), visualizing the odds ratios with 95% confidence intervals for TyG index quartiles across age and sex groups.

indices may benefit from closer surveillance for albuminuria and early stage kidney dysfunction. This aligns with the findings of Jinli et al who demonstrated that a high TyG index predicts poor clinical outcomes and may serve as a novel prognostic indicator among patients with RFI.¹⁸

TyG Index and Metabolic Syndrome

The TyG index has been extensively studied as a surrogate marker of IR, and is closely associated with metabolic syndrome components, including abdominal obesity, dyslipidemia, hypertension, and hyperglycemia. In our study, we observed that TyG index levels increased with BMI, WHtR, triglyceride and glucose levels, and blood pressure, whereas HDL-C levels decreased, which is consistent with previous reports. Guerrero-Romero et al and Zhang et al originally proposed the TyG index as a simple, convenient, and cost-effective indicator of IR,^{19,20} and further studies have confirmed its utility in identifying individuals with metabolic syndrome.^{21,22} In longitudinal analyses, higher TyG index values have also been shown to predict the future development of diabetes, hypertension, cardiovascular disease, and worsening kidney function, even among those not meeting the diagnostic criteria at baseline.^{5,23,24} These associations may be driven by IR-related mechanisms such as impaired lipolysis, reduced glucose uptake in muscle tissue, and chronic inflammation.²⁵

TyG Index and Renal Function

Renal function is conventionally assessed using eGFR and albuminuria; however, identifying early and modifiable predictors remains crucial. Our study revealed a clear upward trend in the prevalence of albuminuria and RFI across the TyG index quartiles, particularly among women.

Although the underlying mechanisms remain partially understood, IR appears to play a central role in renal injury via endothelial dysfunction, oxidative stress, chronic inflammation, such as interleukin-6 and tumor necrosis factor- α , all of which contribute to glomerular hyperfiltration and progressive nephron damage.^{26,27} The kidney is a highly metabolically active organ with abundant mitochondrial oxidation, which makes it particularly susceptible to oxidative stress (OS). In kidney disease, OS arises from both the depletion of antioxidants and the overproduction of reactive oxygen species, which together contribute to kidney damage.²⁸ Excessive activation of the renin-angiotensin system leads to elevated levels of angiotensin II, which affects the entire circulatory system and has a particularly strong impact on the kidneys. This results in high blood pressure and promotes inflammation and fibrosis within the kidney tissue, which together contribute to the development of RFI.²⁹ Furthermore, variability in the TyG index has been associated with CKD progression, particularly in hypertensive patients with normal diastolic blood pressure.³⁰ Jiang et al also demonstrated that TyG-BMI is a strong independent predictor of diabetes and diabetic kidney disease, underscoring the compounding impact of adiposity on the metabolic burden.³¹

Sex Differences in the TyG–RFI Association

A notable finding in our study was the sex-specific pattern of association between TyG index and RFI, with a significantly stronger correlation observed in women aged ≥ 50 years, especially since menopause usually starts around this age in women. With advancing age, women experience a decline in ovarian function and reduced estrogen levels, leading to multiple symptoms associated with menopause.³² This may be attributed to the hormonal changes that accompany menopause. Estrogen improves insulin sensitivity and metabolic profiles by modulating estrogen receptors in the liver and adipose and muscle tissues.³³ In postmenopausal women, IR is more often attributed to weight gain or central obesity, which are the most frequent metabolic conditions associated with aging and reduced estrogen levels,^{34,35} Consequently, a postmenopausal estrogen decline is associated with increased visceral adiposity and IR, which may potentiate renal injury and decrease insulin sensitivity.

Consistent with these observations, previous studies have reported higher TyG indices in men than in women, possibly because of the protective effects.³⁶ However, postmenopausal women may experience greater metabolic deterioration than men, contributing to their heightened RFI risk despite their lower absolute TyG levels. A large cohort study found that TyG-BMI was an independent predictor of RFI, with the association notably stronger in women and individuals under 60 years of age.³⁷

Strengths and Limitations

This study has several strengths. First, the large sample size allowed for robust stratification according to age and sex, which enhanced the clinical relevance of the findings. Second, although our multivariate analysis was adjusted for BMI and MAP, it did not account for other potential confounders such as smoking, socioeconomic status, diet, and physical activity. Third, the focus on Asian populations helps to fill an important gap in the literature, as most TyG-based renal studies have been conducted in Western populations. Fourth, the integration of anthropometric, metabolic, and renal indices provided a comprehensive assessment of the predictive value of the TyG index. Finally, a longitudinal follow-up is required to confirm the directionality of this relationship.

However, some limitations of this study should be noted. The cross-sectional design precludes the inference of causality. Participants were drawn from a health examination cohort, who were likely healthier and younger than the general population, potentially introducing selection bias. Additionally, this was a single-center study limited to Chinese adults, which may restrict the generalizability to other ethnic or geographic populations. Future longitudinal multicenter studies are warranted to confirm these findings and explore their causality.

Conclusion

This study demonstrates that an elevated TyG index is independently associated with increased risk of RFI, especially among women aged ≥ 50 years. Given its simplicity, cost-effectiveness, and strong predictive value, the TyG index may serve as a useful clinical marker for the early identification of individuals at risk of RFI. Beyond clinical screening, the TyG index could help guide preventive strategies in populations at risk, such as postmenopausal women. Future research should validate these findings in multicenter and multiethnic cohorts, explore underlying biological mechanisms, and assess the predictive utility of TyG index in longitudinal studies to confirm causality.

Abbreviations

TyG, triglyceride-glucose; CKD, chronic kidney disease; IR, insulin resistance; BMI, body mass index; WHtR, waist-to-height ratio; MBP, mean blood pressure; ORs, odd ratios; CI, confidence intervals; FPG, fasting plasma glucose; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ACR, urine albumin-to-creatinine ratio; RFI, renal function impairment; ESRD, end-stage renal disease; OS, oxidative stress.

Ethics Approval

Ethical approval for this study was obtained from Institutional Review Board of Chang-Gung Memorial Hospital (XMCGIRB2022107) and was conducted in accordance with the guidelines laid down in the Declaration of Helsinki.

Informed Consent

The study was approved by Institutional Review Board of Chang-Gung Memorial Hospital (XMCGIRB2022107) and exempted from informed consent requirements by the Xiamen Chang-Gung Memorial Hospital Medical Ethics Committee as it used de-identified retrospective data, posed minimal risk, and analyzed only group-level data.

Acknowledgments

We thank the staff in the Health Management Center of Chang Gung Hospital for data collection assistance.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Disclosure

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Kovesdy CP. Epidemiology of chronic kidney disease: an update 2022. *Kidney Int Suppl.* 2022;12(1):7–11. doi:10.1016/j.kisu.2021.11.003
2. Liyanage T, Toyama T, Hockham C, et al. Prevalence of chronic kidney disease in Asia: a systematic review and analysis. *BMJ Glob Health.* 2022;7(1):e007525. doi:10.1136/bmjgh-2021-007525
3. Vos T, Bikbov B, Levey AS. Global, regional, and national burden of chronic kidney disease, 1990–2017: a systematic analysis for the global burden of disease study 2017. *Lancet.* 2020;395(10225):709–733. doi:10.1016/S0140-6736(20)30045-3
4. Erfanpoor S, Etemad K, Kazempour S, et al. Diabetes, hypertension, and incidence of chronic kidney disease: is there any multiplicative or additive interaction? *Int J Endocrinol Metab.* 2020;19(1):e101061. doi:10.5812/ijem.101061
5. Tarabeih M, Qaddumi J, Hamdan Z, Bahar A, Sawalmeh O. Worsening of diabetes control measures and decreased kidney function in pre-diabetic kidney donors compared to non-diabetic donors whose BMI before kidney donation was above 30. *Transplant Proc.* 2024;56(6):1332–1340. doi:10.1016/j.transproceed.2024.05.038
6. Sabanayagam C, Lim CC. Kidney failure trends in people with diabetes: the looming epidemic. *Lancet Reg Health West Pac.* 2021;12:100173. doi:10.1016/j.lanwpc.2021.100173
7. Xuefei Z, Xuedong A, Cunqing Y, Wenjie S, Hangyu J, Fengmei L. The crucial role and mechanism of insulin resistance in metabolic disease. *Front Endocrinol.* 2023;14:1149239. doi:10.3389/fendo.2023.1149239
8. Shan Y, Liu Q, Gao T. Triglyceride-glucose index in predicting the risk of new-onset diabetes in the general population aged 45 years and older: a national prospective cohort study. *BMC Endocr Disord.* 2025;25(1):25. doi:10.1186/s12902-025-01848-w
9. Simental-Mendía LE, Rodríguez-Morán M, Guerrero-Romero F. The product of fasting glucose and triglycerides as surrogate for identifying insulin resistance in apparently healthy subjects. *Metab Syndr Relat Disord.* 2008;6(4):299–304. doi:10.1089/met.2008.0034
10. Guo W, Zhu W, Wu J, et al. Triglyceride glucose index is associated with arterial stiffness and 10-year cardiovascular disease risk in a Chinese population. *Front Cardiovasc Med.* 2021;8:585776. doi:10.3389/fcvm.2021.585776
11. Tao LC, Xu JN, Wang TT, et al. Triglyceride-glucose index as a marker in cardiovascular diseases: landscape and limitations. *Cardiovasc Diabetol.* 2022;21(1):68. doi:10.1186/s12933-022-01511-x
12. Mauricio D, Gratacós M, Franch-Nadal J. Diabetic microvascular disease in non-classical beds: the hidden impact beyond the retina, the kidney, and the peripheral nerves. *Cardiovasc Diabetol.* 2023;22(1):314. doi:10.1186/s12933-023-02056-3
13. Madonna R, Balistreri CR, Geng YJ, Caterina RD. Diabetic microangiopathy: pathogenetic insights and novel therapeutic approaches. *Vascul Pharmacol.* 2017;90:1–7. doi:10.1016/j.vph.2017.01.004
14. Ren X, Jiang M, Han L, Zheng X. Association between triglyceride-glucose index and chronic kidney disease: a cohort study and meta-analysis. *Nutr Metab Cardiovasc Dis.* 2023;33(6):1121–1128. doi:10.1016/j.numecd.2023.03.026
15. Mihai S, Codrici E, Popescu ID, et al. Inflammation-related mechanisms in chronic kidney disease prediction, progression, and outcome. *J Immunol Res.* 2018;2018:2180373. doi:10.1155/2018/2180373
16. Levey AS, Coresh J, Greene T, et al. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med.* 2006;145(4):247–254. doi:10.7326/0003-4819-145-4-200608150-00004
17. Keane WF, Eknoyan G. Proteinuria, albuminuria, risk, assessment, detection, elimination (PARADE): a position paper of the national kidney foundation. *Am J Kidney Dis.* 1999;33(5):1004–1010. doi:10.1016/S0272-6386(99)70442-7
18. Tuo J, Zhong L, Xie L. Association between triglyceride-glucose index and clinical outcomes among patients with chronic kidney disease: a meta-analysis. *BMC Nephrol.* 2025;26(1):61. doi:10.1186/s12882-025-03984-w
19. Simental-Mendía LE, Simental-Mendía E, Rodríguez-Hernández H, Rodríguez-Morán M, Guerrero-Romero F. The product of triglycerides and glucose as biomarker for screening simple steatosis and NASH in asymptomatic women. *Ann Hepatol.* 2010;9(7):3347–3351.
20. Zhang L, Zeng L. Non-linear association of triglyceride-glucose index with prevalence of prediabetes and diabetes: a cross-sectional study. *Front Endocrinol.* 2023;13(14):1295641. doi:10.3389/fendo.2023.1295641
21. Unger G, Benozzi SF, Perruzza F, Pennacchiotti GL. Triglycerides and glucose index: a useful tool to evaluate insulin resistance. *Endocrinol Nutr.* 2014;61(10):533–540. doi:10.1016/j.endonu.2014.06.009
22. Lee SH, Han K, Yang HK, et al. Identifying subgroups of obesity using the product of triglycerides and glucose: the Korea national health and nutrition examination survey, 2008–2010. *Clin Endocrinol.* 2016;84(2):213–220.
23. Da Young L, Eun Seo L, Ji Hyun K. Predictive value of triglyceride glucose index for the risk of incident diabetes: a 4-year retrospective longitudinal study. *PLoS One.* 2016;11(9):e0163465. doi:10.1371/journal.pone.0163465
24. Han Z, LiJun W, QingYa Z. Non-linear association of triglyceride-glucose index with cardiovascular and all-cause mortality in T2DM patients with diabetic kidney disease: NHANES 2001–2018 retrospective cohort study. *Lipids Health Dis.* 2024;23(1):253. doi:10.1186/s12944-024-02249-z
25. Kyung Rae K, Chul Woo A, Shinae K, Ji Sun N, Kyung Rae K, Jong Suk P. Relationship between the triglyceride glucose index and coronary artery calcification in Korean adults. *Cardiovasc Diabetol.* 2017;16(1):108. doi:10.1186/s12933-017-0589-4
26. Lee BT, Ahmed FA, Hamm LL, et al. Association of C-reactive protein, tumor necrosis factor- α , and interleukin-6 with chronic kidney disease. *BMC Nephrol.* 2015;16(1):77. doi:10.1186/s12882-015-0068-7
27. DeFronzo RA. Pathogenesis of type 2 diabetes mellitus. *Med Clin North Am.* 2004;88(4):787–835. doi:10.1016/j.mcna.2004.04.013
28. Daenen K, Andries A, Mekahli D, Van Schepdael A, Joutet F, Bammens B. Oxidative stress in chronic kidney disease. *Pediatr Nephrol.* 2019;34(6):975–991. doi:10.1007/s00467-018-4005-4

29. Maranduca MA, Clim A, Pinzariu AC, et al. Role of arterial hypertension and angiotensin II in chronic kidney disease (Review). *Exp Ther Med.* 2023;25(4):153. doi:10.3892/etm.2023.11852
30. Chao Y, Yumeng S, Tao W, et al. Triglyceride–glucose index change and chronic kidney disease progression in a Chinese hypertensive population. *Front. Endocrinol.* 2024;15:1342408.
31. Jiang Y, Lai X. Association between the triglyceride glucose index, triglyceride-glucose body mass index and diabetic kidney disease in adults with newly diagnosed type 2 diabetes. *Front Med.* 2024;11:1328601. doi:10.3389/fmed.2024.1328601
32. Armeni A, Anagnostis P, Armeni E, Mili N, Goulis D, Lambrinoudaki I. Vasomotor symptoms and risk of cardiovascular disease in peri- and postmenopausal women: a systematic review and meta-analysis. *Maturitas.* 2023;171:13–20. doi:10.1016/j.maturitas.2023.02.004
33. Klinge CM. Estrogenic control of mitochondrial function and biogenesis. *J Cel Biochem.* 2008;105(6):1342–1351. doi:10.1002/jcb.21936
34. Chedraui P, Pérez-López FR, Escobar GS, et al. Research group for the Omega women's health project. Circulating leptin, resistin, adiponectin, visfatin, adipon and ghrelin levels and insulin resistance in postmenopausal women with and without the metabolic syndrome. *Maturitas.* 2014;79(1):86–90. doi:10.1016/j.maturitas.2014.06.008
35. Robeva R, Mladenović D, Vesković M, et al. The interplay between metabolic dysregulations and non-alcoholic fatty liver disease in women after menopause. *Maturitas.* 2021;151:22–30. doi:10.1016/j.maturitas.2021.06.012
36. Kautzky-Willer A, Harreiter J, Pacini G. Sex and gender differences in risk, pathophysiology and complications of type 2 diabetes mellitus. *Endocr Rev.* 2016;37(3):278–316. doi:10.1210/er.2015-1137
37. Cheng F, Mengyuan G, Shuye C, Zhaohui W, Tianhui A. Elevated TyG-BMI index predicts incidence of chronic kidney disease. *Clin Exp Med.* 2024;24(1):203. doi:10.1007/s10238-024-01472-3

International Journal of General Medicine

Publish your work in this journal

The International Journal of General Medicine is an international, peer-reviewed open-access journal that focuses on general and internal medicine, pathogenesis, epidemiology, diagnosis, monitoring and treatment protocols. The journal is characterized by the rapid reporting of reviews, original research and clinical studies across all disease areas. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/international-journal-of-general-medicine-journal>

Dovepress
Taylor & Francis Group