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Trabajo Original

Obesidad y síndrome metabólico

The triglyceride glucose-waist circumference is the best indicator for screening non-alcoholic fatty liver disease in middle-aged and elderly people

El índice triglicéridos glucosa-circunferencia de cintura es el mejor indicador para la detección de la enfermedad del hígado graso no alcohólico en personas de mediana edad y mayoresa

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Abstract

Background: this investigation aimed to assess the correlation between the triglyceride glucose (TyG) index and its related indicators, as well as the ratio of triglyceride to high-density lipoprotein cholesterol (TG/HDL-c), with hepatic steatosis and liver fibrosis among middle-aged and elderly participants.

Methods: based on data from the 2017-2020 National Health and Nutrition Examination Survey, the study included adults of ages 40 years and older in the United States. To explore the correlation between TyG and its related indicators, as well as TG/HDL-c with hepatic steatosis and liver fibrosis, multiple regression models were employed. In addition, the receiver operating characteristic curves were used to further explore the diagnostic efficacy of these indicators in non-alcoholic fatty liver disease (NAFLD) and liver fibrosis.

Results: following the adjustment for various possible covariates, TyG, triglyceride glucose-body mass index (TyG-BMI), triglyceride glucose-waist circumference (TyG-WC), as well as TG/HDL-c were positively correlated with controlled attenuation parameter and NAFLD, with corresponding β coefficients of 17.90, 0.19, 0.20, and 1.57, alongside odds ratios of 2.10, 1.01, 1.01, and 1.15, respectively (all $p < 0.05$). The β coefficient for the association between TyG and liver stiffness measurement was -0.43 ($p = 0.023$). Notably, the area under the curve (AUC) of TyG-WC was the highest of all parameters, showing strong diagnostic potential for identifying NAFLD (AUC = 0.79) and liver fibrosis (AUC = 0.75).

Conclusions: this study reveals a significant positive correlation between TyG-WC and the prevalence of NAFLD in middle-aged and elderly people in the United States. These findings highlight that lowering TyG-WC levels may help reduce the incidence of NAFLD in middle-aged and older Americans.

Keywords:

Non-alcoholic fatty liver disease. Liver fibrosis. Triglyceride-glucose index. Obesity. Control attenuation parameters.

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Data availability: The data that support the findings of this study are available in the National Center for Health Statistics at http://www.cdc.gov/nchs/nhanes/.

Ethics approval and consent to participate: All participants provided written informed consent during the survey, and the NCHS Ethics Review Board (ERB) approved this study (Protocol number: 2018-01).

Conflict of interest: The authors declare no conflict of interest.

Artificial intelligence: The authors declare not to have used artificial intelligence (AI) or any AI-assisted technologies in the elaboration of the article.

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Resumen

Introducción: esta investigación tuvo como objetivo evaluar la correlación entre el índice de Triglicéridos Glucosa (TyG) y sus indicadores relacionados, así como la relación de los triglicéridos y el colesterol de lipoproteínas de alta densidad (TG/HDL-c), con la esteatosis hepática y la fibrosis hepática entre participantes de mediana edad y mayores.

Métodos: basado en datos de la Encuesta Nacional de Examen de Salud y Nutrición 2017-2020, el estudio incluyó a adultos de 40 años o más en los Estados Unidos. Para explorar la correlación entre TyG y sus indicadores relacionados, así como de TG/HDL-c con la esteatosis hepática y la fibrosis hepática, se emplearon modelos de regresión multivariados. Además, se utilizaron las curvas de características operativas del receptor para explorar más a fondo la eficacia diagnóstica de estos indicadores en la enfermedad del hígado graso no alcohólico (EHGNA) y la fibrosis hepática.

Resultados: tras el ajuste de las posibles covariables, el TyG, el índice triglicéridos glucosa-masa corporal (TyG-IMC), el índice triglicéridos glucosa-circunferencia de Cintura (TyG-CC), así como el TG/HDL-c se correlacionaron positivamente con el parámetro de atenuación controlada y la EHGNA, obteniéndose coeficientes β de 17,90, 0,19, 0,20 y 1,57, junto con razones de probabilidades de 2,10, 1,01, 1,01 y 1,15, respectivamente (todos com $p < 0,05$). El coeficiente β para la asociación entre TyG y la medición de la rigidez hepática fue de -0,43 ($p = 0,023$). Cabe destacar que el área bajo la curva (AUC) de TyG-WC fue la más alta de todos los parámetros, lo que muestra un fuerte potencial diagnóstico para identificar la EHGNA (AUC = 0,79) y la fibrosis hepática (AUC = 0,75).

Conclusión: este estudio revela una correlación positiva significativa entre TyG-WC y la prevalencia de EHGNA en personas de mediana edad y mayores en los Estados Unidos. Estos hallazgos evidencian que reducir los niveles de TyG-WC puede ayudar a reducir la incidencia de EHGNA en estadounidenses de mediana edad y mayores y que él.

Palabras clave:

Enfermedad del hígado graso no alcohólico. Fibrosis hepática. Índice triglicéridos-glucosa. Obesidad. Parámetros de atenuación de control.

INTRODUCTION

The most prevalent chronic liver condition nowadays is non-alcoholic fatty liver disease (NAFLD). Excessive fat accumulation occurs in liver cells after the exclusion of viral infection or excessive alcohol consumption, which is seen as a disease state. It is closely related to insulin resistance (IR), abnormal lipids, obesity, and other risk factors (1,2). NAFLD is prevalent in both adults and children, with a global occurrence rate of up to 25 % (3). It stands as a major factor leading to the development of liver fibrosis and end-stage liver disease and is likely to result in increased challenges for global public healthcare systems in the forthcoming years (4,5). NAFLD and liver fibrosis are closely related to age. Elderly individuals have shown a higher inclination towards developing hepatic steatosis and liver fibrosis, along with increased risks of disease progression or mortality among older patients with NAFLD (6-8). Due to a limited understanding of the condition, middle-aged and older people with NAFLD are not identified until the condition has progressed to a severe stage. Therefore, the timely detection of NAFLD holds significant importance for healthcare maintenance in middle-aged and elderly populations.

Initially the triglyceride glucose (TyG) index was acknowledged as a dependable substitute marker for evaluating IR (9). Furthermore, a significant role is also played by the ratio of triglycerides to high-density lipoprotein cholesterol (TG/HDL-c) in evaluating IR (10). Due to the pivotal role of IR in NAFLD progression, it has been observed by researchers that TyG and related obesity indices as well as TG/HDL-c can also serve as assessments for adult NAFLD and liver fibrosis. TyG index is considered a reliable indicator of screening for obesity and has been used to assess related metabolic diseases in conjunction with the body mass index (BMI), as is waist circumference (WC). In the two studies by Khamseh et al. (11) and Li et al. (12), it was respectively observed that TyG-WC showed a positive correlation with controlled attenuation parameter (CAP) and liver stiffness measurement (LSM) in overweight/obese adults and non-obese adults. Moreover, TyG-WC demonstrated superior diagnostic capabilities for NAFLD compared to the remaining indicators. This indicates that TyG-WC is anticipated to function as a valuable marker for the evaluation of NAFLD and liver fibrosis.

Nonetheless, data are scarce regarding the correlation between TyG-WC and NAFLD as well as liver fibrosis among middle-aged and elderly individuals in the United States. Therefore, exploring these associations can provide a new perspective for the monitoring and effective management of NAFLD in this population.

MATERIALS AND METHODS

STUDY POPULATION

All participants in this study were sourced from National Health and Nutrition Examination Survey (NHANES) (2017-2020). Among the U.S. population, multistage probability sampling techniques were applied to secure representative samples reflecting the general health conditions. This cross-sectional study approved by the National Center for Health Statistics (NCHS), ensured that written informed consent was obtained from all participants. Public access to detailed measurement procedures for all variables is available at http://www.cdc.gov/nchs/nhanes/.

Finally, the study included 15,560 participants from the NHANES in 2017-2020. After excluding age < 40 years ($n = 9127$), CAP or LSM deletion ($n = 915$), liver stiffness interquartile range (IQRe)/median ≥ 30 % or IQRe/median deletion ($n = 183$), fasting plasma glucose (FPG), TG, WC, BMI, and HDL-c deletion ($n = 2924$), hepatitis B or C patients ($n = 101$), hepatitis B antigen or hepatitis C RNA positive ($n = 19$), excessive alcohol consumption (≥ 4/5 drinks per day, $n = 325$), and lack of information on hemoglobin A1c (HbA1c), drinking, education, and smoking ($n = 96$). This study ultimately involved 1,870 participants. The participant screening process is depicted in figure 1.

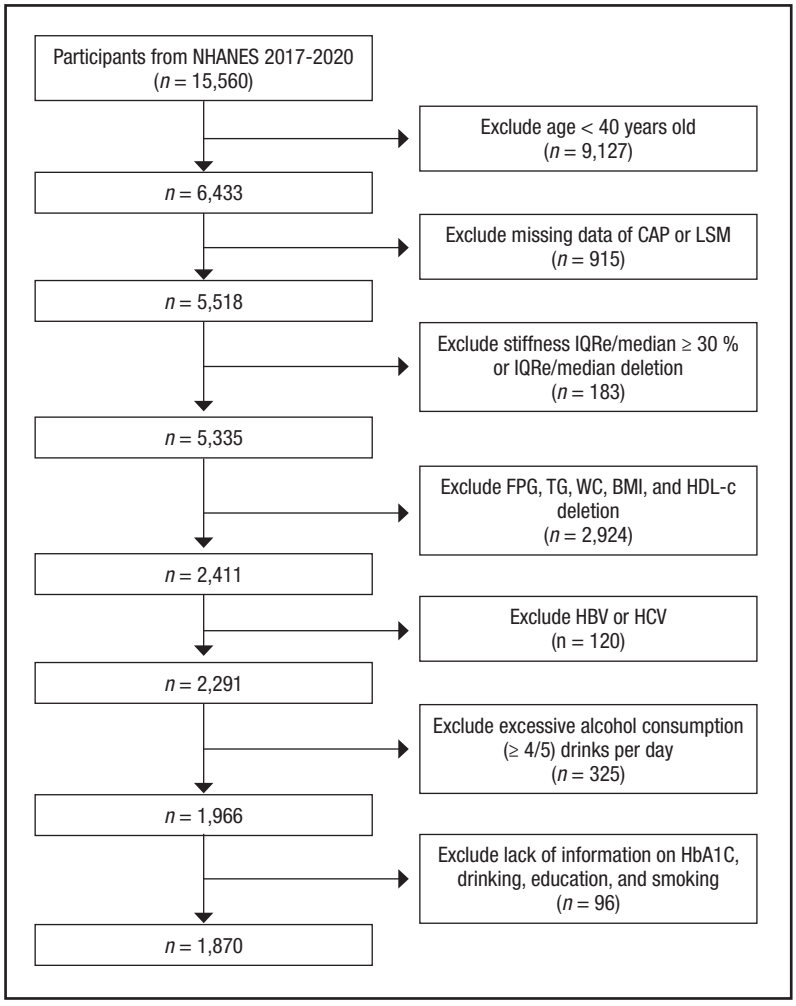

Figure 1.
Flowchart of the sample selection from NHANES 2017-2020.

EXPOSED VARIABLES

The exposed variables in this study were TyG and its obesity markers like TyG-BMI, and TyG-WC, as well as TG/HDL-c. These measurements are based on fasting triglyceride, FPG, BMI, WC, and HDL-c, all of which are closely related to IR and obesity (13).

TyG = Ln[TG (mg/dL) x FPG (mg/dL)/2]

TyG-BMI = TyG × BMI (kg/m^2)

TyG-WC = TyG × WC (cm)

TG/HDL-c = TG (mg/dL) x HDL-c (mg/dL)

OUTCOME VARIABLES

NAFLD and liver fibrosis were seen as outcome variables. The CAP and LSM, obtained through vibration-controlled transient elastography using FibroScan® model 502 V2 Touch device, served as indicators reflecting hepatic steatosis and liver fibrosis. NAFLD was determined by a median CAP ≥ 274 dB/m and liver fibrosis was indicated by LSM ≥ 8 kPa after excluding individuals with hepatitis B or C and heavy drinking (14,15). The test is considered reliable when fasting for at least 3 hours, at least 10 valid measurements are obtained, and the liver stiffness IQRe/median ratio is less than 30 %.

COVARIATES

Covariates included age, gender, race, education level, income to poverty ratio (PIR), moderate activity, smoking, drinking, hypertension, diabetes *mellitus* (DM), BMI, WC, FPG, HbA1c, alanine aminotransferase (ALT), aspartate aminotransferase (AST), gamma-glutamyl transferase (GGT), blood urea nitrogen (BUN), serum creatinine (SCR), serum uric acid (SUA), C-reactive protein (CRP), total cholesterol (TC), HDL-c.

The education level of the participants was categorized based on whether they had completed high school or not. Defined as moderate-intensity activity, such as brisk walking, cycling, swimming, etc., moderate-intensity lasted at least 10 minutes during the week. Smoking and drinking were obtained from questionnaire data. Hypertension was defined by self-reported, systolic blood pressure ≥ 140 mmHg or diastolic blood pressure

≥ 90 mmHg. DM was defined by self-reported, HbA1c ≥ 6.5 % or FPG ≥ 126 mg/dl.

In subgroup analysis, the age variable was categorized into two groups: a) ≥ 40 years old, ≤ 60 years old; and b) > 60 years old, ≤ 80 years old; the BMI variable was divided into three groups: a) ≤ 25 kg/m^2; b) > 25 kg/m^2, ≤ 30 kg/m^2; and c) > 30 kg/m^2.

Demographic variables were obtained at home by NHANES staff using a computer-assisted personal interview system. BMI and WC were measured by trained health technicians in a mobile measurement center. Data on liver and kidney function, fasting plasma glucose, and lipid profiles were obtained from blood samples analyzed by staff at the NHANES laboratory.

STATISTICAL ANALYSIS

For continuous variables, mean values and standard deviations were employed for representation, while percentages were used to present categorical variables. Firstly, multiple regression model analyses were used to analyze the correlation between TyG and its related indicators, as well as TG/HDL-c with hepatic steatosis and liver fibrosis. Model 1 did not involve any adjustments; however, age, gender, and race were adjusted in model 2. Model 3 involved making necessary adjustments for age, gender, race, education level, PIR, moderate activity, smoking, drinking, hypertension, DM, BMI, WC, HbA1c, ALT, AST, GGT, BUN, SCR, SUA, CRP, TC, HDL-c, CAP, and LSM as needed. Then receiver operating characteristic (ROC) curve analysis was used to evaluate the area under the curve (AUC) values. All statistics were analyzed using R 4.2.0 and EmpowerStats 4.1. The study's data analysis utilized suitable NHANES sample weights. The significance level was set at $p < 0.05$.

RESULTS

Were involved in the study 1,870 participants, accounting for 54.6 % female. Their mean age was 60.0 ± 11.6 years. These participants were segregated into two categories depending on the presence of NAFLD. Among them, 927 individuals (49.6 %) were identified with NAFLD, while 943 individuals (50.4 %) were categorized as non-NAFLD groups. In the NAFLD group, the average CAP was measured at 321.97 dB/m, while the mean LSM recorded was 6.41 kpa. The NAFLD group tended to be male, Mexican American, inactivity, hypertension, and DM, and the NAFLD group exhibited higher levels of BMI, WC, FPG, HbA1C, ALT, AST, GGT, BUN, SUA, CRP, TG, CAP, and LSM (all $p < 0.05$). It was worth noting that TyG and its indicators along with TG/HDL-c in NAFLD patients were significantly elevated compared to those in the control group ($p < 0.001$). Table I provides basic information about the participants.

Table I. Weighted characteristics of participants included in the study

Characteristics	Total (*n* = 1870)	Non-NAFLD (*n* = 943)	NAFLD (*n* = 927)	*p*-value
Age (years)	58.3 ± 11.3	57.9 ± 11.7	58.8 ± 10.9	0.069
Gender (%)				
Male	45.1	40.9	49.5	< 0.001
Female	54.9	59.1	50.5	
Race (%)				
Mexican American	6.4	4.8	8.1	
Other Hispanic	6.7	7.1	6.2	
Non-Hispanic white	67.9	68.2	67.5	0.038
Non-Hispanic black	9.6	10.4	8.8	
Other race	9.4	9.5	9.4	
Education (%)				
Less than high school	11.3	11.7	10.8	
High school or equivalent	25.8	23.6	28.3	0.067
More than high school	62.9	64.7	60.9	
PIR	3.37 ± 1.50	3.39 ± 1.47	3.35 ± 1.54	0.597
Moderate activity (%)				
No	49.8	46.7	53.1	0.006
Yes	50.2	53.3	46.9	

(Continues on next page)

Table I (cont.). Weighted characteristics of participants included in the study

Characteristics	Total (*n* = 1870)	Non-NAFLD (*n* = 943)	NAFLD (*n* = 927)	*p*-value
Smoked at least 100 cigarettes (%)				
No	58.7	60.0	53.1	0.260
Yes	41.3	40.0	46.9	
Drinking alcohol (%)				
No	7.8	7.3	8.3	0.393
Yes	92.2	92.7	91.7	
Hypertension (%)				
No	59.3	68.3	49.7	< 0.001
Yes	40.7	31.7	50.3	
DM (%)				
No	83.8	90.5	76.5	< 0.001
Yes	16.2	9.5	23.5	
BMI	29.58 ± 6.31	26.88 ± 4.91	32.48 ± 6.37	< 0.001
WC	101.58 ± 15.11	94.46 ± 12.30	109.24 ± 14.06	< 0.001
FPG	113.35 ± 33.46	106.19 ± 24.46	121.05 ± 39.56	< 0.001
HbA1c	5.84 ± 0.94	5.65 ± 0.76	6.04 ± 1.07	< 0.001
ALT	21.59 ± 12.69	19.38 ± 11.03	23.96 ± 13.87	< 0.001
AST	20.91 ± 8.60	20.26 ± 6.58	21.60 ± 10.30	< 0.001
GGT	28.73 ± 31.46	25.56 ± 27.35	32.12 ± 35.03	< 0.001
BUN	15.82 ± 5.58	15.57 ± 5.35	16.08 ± 5.81	0.047
SCR	0.88 ± 0.30	0.89 ± 0.34	0.88 ± 0.25	0.228
SUA	5.40 ± 1.40	5.06 ± 1.36	5.76 ± 1.35	< 0.001
CRP	4.07 ± 7.88	3.52 ± 8.46	4.65 ± 7.16	0.002
TG	115.58 ± 94.15	96.24 ± 57.50	136.37 ± 118.36	< 0.001
TC	192.59 ± 40.63	194.14 ± 39.26	190.92 ± 41.99	0.087
HDL	55.26 ± 16.41	58.65 ± 16.27	51.61 ± 15.77	< 0.001
TyG	8.61 ± 0.63	8.40 ± 0.54	8.82 ± 0.64	< 0.001
TyG-BMI	255.56 ± 62.05	226.55 ± 47.67	286.73 ± 60.58	< 0.001
TyG-WC	877.06 ± 161.43	795.74 ± 129.42	964.46 ± 146.01	< 0.001
TG/HDL-c	2.49 ± 3.14	1.90 ± 1.79	3.12 ± 4.03	< 0.001
CAP	272.43 ± 59.30	226.34 ± 34.49	321.97 ± 35.79	< 0.001
LSM	5.67 ± 3.52	4.98 ± 2.50	6.41 ± 4.24	< 0.001
Liver fibrosis (%)				
No	90.3	95.6	84.5	< 0.001
Yes	9.7	4.4	15.5	

Continuous variables in the table are presented as weighted means and categorical variables as weighted percentages. PIR: income to poverty ratio; DM: diabetes mellitus; BMI: body mass index; WC: waist circumference; FPG: fasting plasma glucose; HbA1c: hemoglobin A1c; ALT: alanine aminotransferase; AST: aspartate aminotransferase; GGT: gamma-glutamyl transferase; BUN: blood urea nitrogen; SCR: serum creatinine; SUA: serum uric acid; CRP: C-reactive protein; TG: triglyceride; TC: total cholesterol; HDL-c: high-density lipoprotein cholesterol; TyG: triglyceride glucose; TyG-BMI: triglyceride glucose-body mass index; TyG-WC: triglyceride glucose-waist circumference; TG/HDL: triglyceride/high-density lipoprotein cholesterol; CAP: controlled attenuation parameter; LSM: liver stiffness measurement; NAFLD: non-alcoholic fatty liver disease.

After adjusting for all potential confounders, this study found that TyG, TyG-BMI, TyG-WC, along with TG/HDL-c were positively correlated with CAP and NAFLD, with their βs (95 %CI) respectively being 17.90 (12.89, 22.92), 0.19 (0.11, 0.28), 0.20 (0.16, 0.23), and 1.57 (0.89, 2.26) (all $p < 0.001$), and with their ORs (95 %CI) respectively being 2.10 (1.61, 2.74), 1.01 (1.00, 1.01), 1.01 (1.01, 1.01), and 1.15 (1.08, 1.23) (all $p < 0.05$) (Table II).

In addition, after adjusting for all potential confounders, TyG was found to be negatively correlated with LSM, β being -0.43 (-0.81, -0.06) ($p = 0.023$) (Table III).

In middle-aged and elderly Americans, the diagnostic performance of all indicators above for NAFLD and liver fibrosis was investigated through ROC curve analysis (Tables IV and V). The most robust diagnostic capability for NAFLD (AUC = 0.79) and liver fibrosis (AUC = 0.75) was exhibited by TyG-WC among them. For predicting NAFLD, the specificity and sensitivity of TyG-WC were 0.71 and 0.73, respectively, with an optimal threshold of 864.49. Regarding the prediction of liver fibrosis, the specificity and sensitivity of TyG-WC were 0.75 and 0.67, respectively, with an optimal threshold of 960.33. ROC curves are shown in figure 2.

Table II. The association between TyG, TyG-BMI, TyG-WC, TG/HDL-c with CAP and NAFLD (CAP ≥ 274 dB/m)

Exposure	CAP (dB/m) [β (95 %CI) *p*-value]	NAFLD [OR (95 %CI) *p*-value]
TyG	17.90 (12.89, 22.92) < 0.001	2.10 (1.61, 2.74) < 0.001
TyG-BMI	0.19 (0.11, 0.28) < 0.001	1.01 (1.00, 1.01) 0.008
TyG-WC	0.20 (0.16, 0.23) < 0.001	1.01 (1.01, 1.01) < 0.001
TG/HDL-c	1.57 (0.89, 2.26) < 0.001	1.15 (1.08, 1.23) < 0.001

Age, gender, race, education level, PIR, moderate activity, smoking, drinking, hypertension, DM, BMI, WC, HbA1C, ALT, AST, GGT, BUN, SCr, SUA, CRP, TC, HDL-c, and LSM were adjusted. For the index of TyG-BMI, BMI was not adjusted. For the index of TyG-WC, WC was not adjusted. For the index of TG/HDL-c, HDL-c was not adjusted. TyG = Ln[TG (mg/dL)×FPG (mg/dL)/2], TyG-BMI = TyG×BMI, TyG-WC = TyG×WC, TG/HDL-c: ratio of TG to HDL-c.

Table III. The association between TyG, TyG-BMI, TyG-WC, TG/HDL-c with LSM and liver stifness (LSM ≥ 8 kpa)

Exposure	LSM (kpa) [β (95 %CI) *p*-value]	Liver fibrosis [OR (95 %CI) *p*-value]
TyG	-0.43 (-0.81, -0.06) 0.023	0.74 (0.50, 1.10) 0.138
TyG-BMI	0.00 (-0.00, 0.01) 0.247	1.00 (1.00, 1.01) 0.182
TyG-WC	0.00 (-0.00, 0.00) 0.520	1.00 (1.00, 1.00) 0.771
TG/HDL	-0.02 (-0.07, 0.03) 0.363	1.00 (0.94, 1.05) 0.849

Author's contribution: Y. Y., and Y. L. analyzed the data and wrote the manuscript. H. Z., and J. G. designed the study. J. C. S., Y. Y. Y., and X. Y. D. collected the data. All authors contributed a lot to the article and approved the submitted version.

Table IV. AUC of TyG, TyG-BMI, TyG-WC, TG/HDL-C, BMI, WC for diagnosing NAFLD

Variables	AUC	95 %CI low	95 %CI upp	Best threshold	Specificity	Sensitivity
TyG	0.71	0.68	0.73	8.65	0.69	0.63
TyG-BMI	0.78	0.76	0.80	234.99	0.61	0.82
TyG-WC	0.79	0.77	0.81	864.49	0.71	0.73
TG/HDL	0.69	0.67	0.72	1.82	0.64	0.69
BMI	0.74	0.72	0.76	28.75	0.68	0.69
WC	0.76	0.74	0.78	99.55	0.67	0.72

TyG = Ln[TG (mg/dL)×FPG (mg/dL)/2], TyG-BMI = TyG×BMI, TyG-WC = TyG×WC, TG/HDL-c: ration of TG to HDL-c, BMI: body mass index; WC: waist circumference; AUC: area under the curve.

Table V. AUC of TyG, TyG-BMI, TyG-WC, TG/HDL-C, BMI, WC for diagnosing liver stifness

Variables	AUC	95 %CI low	95 %CI upp	Best threshold	Specificity	Sensitivity
TyG	0.61	0.57	0.65	8.67	0.56	0.63
TyG-BMI	0.73	0.68	0.77	274.78	0.70	0.68
TyG-WC	0.75	0.71	0.79	960.33	0.75	0.67
TG/HDL-c	0.59	0.55	0.63	1.86	0.51	0.67
BMI	0.71	0.67	0.75	31.65	0.71	0.63
WC	0.74	0.70	0.78	109.65	0.75	0.67

TyG = Ln[TG (mg/dL)×FPG (mg/dL)/2], TyG-BMI = TyG×BMI, TyG-WC = TyG×WC, TG/HDL-c: ration of TG to HDL-c; BMI: body mass index; WC: waist circumference; AUC: area under the curve.

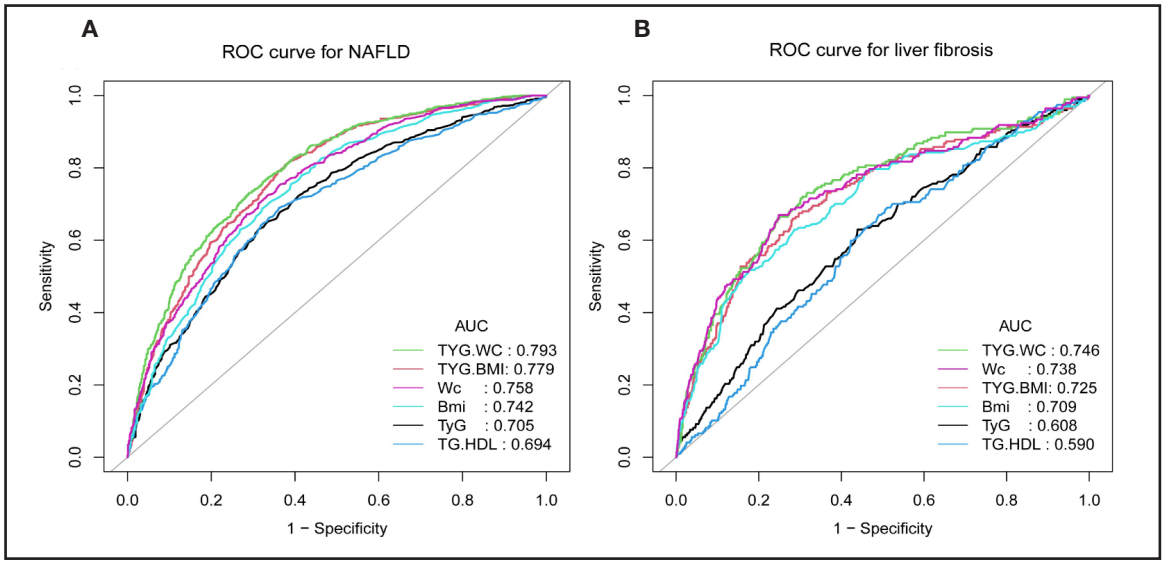

Figure 2.
ROC curves for NAFLD (A) and liver fibrosis (B).

DISCUSSION

Significant positive correlations were observed between TyG and its indicators, as well as TG/HDL-c with CAP and NAFLD among middle-aged and elderly individuals in the United States, based on the findings of this study. In addition, this study found a significant negative correlation between TyG and LSM. In this investigation, the diagnostic efficacy of each aforementioned indicator for NAFLD and liver fibrosis was evaluated. Among these indicators, the TyG-WC index was identified as having superior diagnostic performance, exhibiting an AUC of 0.79 for NAFLD and 0.75 for liver fibrosis.

Despite the rising global prevalence of NAFLD, the prevalence of NAFLD has varied widely across studies, ranging from 7.0 % to 27.0 % (16-18). This difference is attributed to differences in study populations, diagnostic methods used, disease assessment criteria, and geographic impact. Younossi et al. (19) found that the Middle East had the highest prevalence of NAFLD (31.8 %), while Africa had the lowest prevalence (13.5 %). In a prospective study, the prevalence of NAFLD was evaluated in a cohort of older adults with an average age of 85.6 ± 3.8 years, revealing a higher prevalence rate of 46.2 % compared to the general population (20). This study also found similar conclusions, namely, the prevalence of NAFLD in middle-aged and older adults in the United States was 49.6 %. The high prevalence of NAFLD in this study might be attributed to two factors, including a relatively low CAP cut-off in the diagnostic criteria for NAFLD, and the fact that middle-aged and older adults have more risk factors for NAFLD, such as obesity, hypertension, and other metabolic diseases. Because the signs and symptoms of NAFLD patients are not obvious, as well as the limited knowledge of the disease, a significant number of people are not detected until the condition is severe, especially in the middle-aged and elderly. Consequently, early identification of NAFLD is essential for individuals in middle and older age groups.

The correlation between NAFLD with TyG index and TG/HDL-c has been examined in previous studies. Prior research (21,22) has indicated that the TyG index can serve as a valuable alternative for IR. Several studies (9,23) have demonstrated that the TyG index can successfully identify patients with NAFLD due to

the significant involvement of IR in its development. BMI and WC are commonly used to assess overall obesity and central obesity, respectively, and are crucial factors in detecting NAFLD (24,25). Khamseh et al. (11) and Pang et al. (26) discovered a stronger correlation between WC and higher CAP and a higher prevalence of NAFLD compared to BMI. The findings suggested that the accumulation of subcutaneous fat and visceral fat, represented by WC, exerted a more significant influence on IR than general obesity. This phenomenon arises from the heightened production of free fatty acids, inflammatory cytokines, and adipokines by visceral adipose tissue, fostering the progression of NAFLD. Some scholars (11,27,28) pointed out that the TyG index combined with the obesity indicators was better than each index alone in predicting NAFLD, and emphasized that TyG-WC was one of the important factors in predicting NAFLD among all combined indexes. A study (29) involving 12,757 adults in South Korea found that higher levels of WC, BMI, TyG, TyG-BMI, TyG-WC, and fatty liver index were associated with a higher prevalence of NAFLD and that TyG-WC's ability to diagnose NAFLD (AUC = 0.85, 95 % CI: 0.84-0.86) was second only to fatty liver index. A 2021 study from Iranian showed that TyG promoted the progression of liver fibrosis in patients diagnosed with NAFLD (30). In two recent investigations, a correlation between TG/HDL-c and NAFLD has been confirmed, with respective predictive capacities of 0.73 and 0.68 for identifying NAFLD (12,31). In this study, it was observed that middle-aged and elderly Americans with elevated levels of TyG-WC had an increased tendency to suffer from NAFLD, and the ability of TyG-WC to diagnose NAFLD in this population was superior to other indicators. The results of this investigation confirm that higher levels of TyG-WC impair liver health and that TyG-WC facilitates early mass screening for NAFLD in this population, in alignment with prior research.

This study found that except for the significant negative correlation between TyG and LSM, there was no statistical significance between the remaining indicators with LSM and liver fibrosis. Tyg-WC had the strongest diagnostic ability for liver fibrosis, with an AUC of 0.75. This was inconsistent with some previous studies. In the study by Tutunch et al. (30), it was observed that there existed a notable positive correlation between TyG and the advancement of liver fibrosis in patients with NAFLD, but its diagnostic ability for liver fibrosis was low. A study by Li et al. (12) also found that TyG-WC had a low diagnostic ability for liver fibrosis in non-obese people, with an AUC of 0.66, which was also found in non-diabetic obese and overweight patients (AUC = 0.62). The outcomes of this study demonstrated that higher TyG values correlated with lower LSM in the middle-aged and elderly population. It was suggested that TyG may have a protective effect on the progression of liver disease within this group. Abnormal lipid metabolism in patients with NAFLD is usually manifested by elevated serum TC or TG levels. However, as liver disease progresses to fibrosis, or even cirrhosis, liver metabolic function decreases, including insufficient glycogen reserves, reduced carbohydrate oxidation rate, increased lipid oxidation rate, and lipoprotein damage occurs, which may lead to increased levels of inflammatory cytokines in the body. In a study conducted with 1,727 American adults, it was also determined that the TyG-WC index is more effective at diagnosing liver fibrosis compared to using the TyG index alone (32).

In the past, hepatitis B and C were prevalent, whereas a substantial rise in the global incidence of NAFLD is anticipated in the forthcoming years (33). Despite extensive research into treatment options for NAFLD over recent decades, outcomes have remained generally unsatisfactory. Consequently, clinical treatment strategies have been centered on promoting healthy lifestyle choices, managing weight, and preventing complications. Given the reversibility of early-stage NAFLD in patients, the timely identification and treatment of NAFLD hold significant importance for the prognosis of individuals within this population. It is suggested by this study that the employment of TyG-WC could potentially assist certain middle-aged and elderly individuals who have not yet received a diagnosis in making a preliminary assessment of whether they are afflicted with NAFLD.

Our research has three strengths. First, the selective use of all items from a representative population in the NHANES database enhanced the generalizability and confidence of the findings. Secondly, this analysis mainly focused on middle-aged and elderly people in the United States, which was an extension and supplement to the current research on the correlation between TyG-WC and NAFLD and liver fibrosis. Third, as a simple and effective indicator for the evaluation of NAFLD and liver fibrosis, TyG-WC was beneficial to the early identification and treatment of the disease. Some limitations naturally accompany this study. Firstly, the causal correlation of TyG-WC with NAFLD and liver fibrosis could not be known in this study. Secondly, the study was unable to completely account for all potential confounding factors. Lastly, future research based on liver biopsy is needed to further validate these findings.

CONCLUSIONS

In summary, our study suggested that a notable connection was found between elevated TyG-WC levels and a higher prevalence of NAFLD among middle-aged and elderly individuals in the United States. These results support that lowering TyG-WC levels may help reduce the incidence of NAFLD within this demographic.

AUTHOR'S CONTRIBUTION

Y. Y., and Y. L. analyzed the data and wrote the manuscript. H. Z., and J. G. designed the study. J. C. S., Y. Y. Y., and X. Y. D. collected the data. All authors contributed a lot to the article and approved the submitted version.

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