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Relationship between obesity indexes and triglyceride glucose index with gastrointestinal cancer among the US population

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ABSTRACT

Background: Previous studies have found that obesity is closely related to gastrointestinal cancer (GIC), but there is insufficient evidence to compare the relationship between various obesity indexes and triglyceride glucose index with GIC.

Methods: This study analyzed the relationship between Body mass index (BMI), lipid accumulation product (LAP), Triglyceride glucose (TyG), Triglyceride glucose-body mass index (TyG-BMI), Triglyceride glucose-waist circumference (TyG-Waist), Triglyceride Waist-to-Height Ratio (TyG-WHtR), Visceral adiposity index (VAI), Waist circumference (Waist), Waist-to-Height Ratio (WHtR), and Weight-adjusted waist index (WWI) and GIC. The data from National Health and Nutrition Examination Survey from 1999 to 2018 was utilized. We conducted weighted multiple logistic regression to analyze the relationship between GIC and obesity indexes and subgroup analysis was carried out for further study. After that, survival analysis and restricted cubic spline (RCS)was used to analyze the relationship between various obesity indexes and the prognosis of GIC.

Results: Logistic regression showed that TyG [Q4 vs Q1: OR (95 %CI) = 2.082(1.016 ~ 4.269)] and LAP [Q4 vs Q1: OR (95 %CI) = 2.046(1.010 ~ 4.145)] were related to GIC. Survival analysis and RCS found BMI [Q4 vs Q1: HR (95 %CI) = 0.369(0.176 ~ 0.773)], Waist [Q4 vs Q1: HR (95 %CI) = 0.381(0.193 ~ 0.753)], and WWI [Q4 vs Q1: HR (95 %CI) = 0.403(0.188 ~ 0.864)] were significantly related to the prognosis of GIC.

Conclusion: There is a complex relationship between obesity and TyG with GIC. Certain indexes may be utilized to assist patients in developing suitable prevention and lifestyle strategies.

1. Introduction

Gastrointestinal cancers (GIC) have a high incidence and mortality rate, which brings a heavy disease burden to the whole world (Sung et al., 2021). At present, some studies found that GIC is related to obesity, and some studies have tried to explain this from the mechanism (Loosen et al., 2022; Matsui et al., 2022).

However, most studies mainly focus on BMI and other conventional obesity indicators (Mitchelson et al., 2024). Recently some emerging index like TyG have shown good application value in part of cancer (Jung et al., 2022). but there is insufficient evidence to compare the relationship between these emerging indexes and GIC.

Therefore, this study used National Health and Nutrition Examination Survey (NHANES) from 1999 to 2018 to analyze the relationship between ten obesity indexes and GIC, and did subgroup analysis to further analyze the application value of these indexes in different populations. After that, we conduct a cohort analysis through the data with the longest follow-up of 20 years.

Abbreviations: BMI, Body mass index; FBG, Fsting blood glucose; GIC, Gastrointestinal cancers; HDL, high-density lipoprotein; LAP, lipid accumulation product; NHANES, National Health and Nutrition Examination Survey; RCS, Restricted cubic spline; TG, triglyceride; TyG, Triglyceride glucose; TyG-BMI, Triglyceride glucose-body mass index; TyG-Waist, Triglyceride glucose-waist circumference; TyG-WHtR, Triglyceride Waist-to-Height Ratio; VAI, Visceral adiposity index; Waist, Waist circumference; WHtR, Waist-to-Height Ratio; WWI, Weight-adjusted waist index.

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Table 1
Baseline of selected characteristics of U.S. adults, NHANES 1999–2018.

	GIC group (N = 187) % or median	Control group(N = 21224) % or median
Age, years	73.0	50.0
Male, %	93 (49.7)	10,531 (49.6)
Race/Ethnicity, %		
Mexican American	19 (10.2)	3869 (18.2)
Other Hispanic	13 (7.0)	1875 (8.8)
Non-Hispanic White	118 (63.1)	9308 (43.9)
Non-Hispanic Black	28 (15.0)	4199 (19.8)
Other races	9 (4.8)	1973(9.4)
Education level, %		
<9th grade	31 (16.6)	2678 (12.6)
9-11th grade	34 (18.2)	3247 (15.3)
High school	47 (25.1)	4829 (22.8)
College	47 (25.1)	5795 (27.3)
Graduate or above	28 (15.0)	4650 (21.9)
Other	0 (0)	25 (0.1)
Poverty	2.10	2.16
BMI, Kg/m^2	27.5	27.9
Smoker, %	113 (60.4)	9843 (46.4)
Drinker, %	99 (52.9)	12,643 (59.6)
Fasting Glucose, mmol/L	117	108
triglyceride, mmol/L	1.56	1.50
High-density lipoprotein, mmol/L	1.41	1.38
Diabetes, %	42 (22.5)	2608 (12.3)
Hypertension, %	118 (63.1)	7588 (35.8)
Follow-up time, months	66	110

BMI, Body mass index; GIC, Gastrointestinal cancers; NHANES, National Health and Nutrition Examination Survey.

2. Methods

2.1. Participant

Participants in NHANES from 1999 to 2018 were included in this study for analysis. In this study, patients with esophageal cancer, gastric cancer, colorectal cancer, liver cancer, and pancreatic cancer were defined as patients with gastrointestinal cancers. A total of 107,622 participants were enrolled in the screening, and 74,443 patients were excluded due to the lack of relevant data for the calculation of the obesity index. After that, 7411 participants who were less than 20 years old and 609 pregnant women were excluded. A total of 21,411 participants were included to analyze the relationship between multiple obesity indexes and GIC. And 187 participants with GIC was included for survival analysis.

2.2. Obesity index and Triglyceride glucose index

Ten obesity indexes were analyzed in this study, including Body mass index (BMI), lipid accumulation product (LAP), Triglyceride glucose (TyG), Triglyceride glucose-body mass index (TyG-BMI), Triglyceride glucose-waist circumference (TyG-Waist), Triglyceride Waist-to-Height Ratio (TyG-WHtR), Visceral adiposity index (VAI), Waist circumference (Waist), Waist-to-Height Ratio (WHtR), and Weight-adjusted waist index (WWI). These indexes are calculated by height, weight, waist circumference (Waist), fasting blood glucose (FBG), high-density lipoprotein (HDL), and triglyceride (TG) measured by NHANES. And the obesity index of participants was classified into four categories.

These indexes were calculated according to the following formulas: (1) BMI = weight (kg)/height^2 (m^2);(2) LAP = [Waist (cm) − 65] × TG (mmol/L) for males, LAP = [Waist (cm) − 58] × TG (mmol/L) for females; (3) TyG = Ln [TG (mg/dL) × FBG (mg/dL)/2]; (4) TyG-BMI = TyG index × BMI; (5) TyG-Waist = TyG × Waist; (6) TyG-WHtR = TyG × WHtR; (7) VAI = [Waist (cm)/(39.68 + 1.88 × BMI (kg/m^2))] × [TG (mmol/L)/1.03] × [1.31/HDL (mmol/L)], for male; [Waist (cm)/(36.58 + 1.89 × BMI (kg/m^2))] × (TG (mmol/L)/0.81) × (1.52/HDL (mmol/

Table 2
Relationship between obesity indexes and GIC in U.S. adults, NHANES 1999–2018.

	Model 1		Model 2		Model 3	
	OR (95CI%)	P	OR (95CI%)	P	OR (95CI%)	P
BMI						
Q1	Ref		Ref		Ref	
Q2	1.895(1.144 ~ 3.138)	0.014	1.582(0.938 ~ 2.669)	0.085	1.504(0.903 ~ 2.505)	0.116
Q3	1.171(0.660 ~ 2.078)	0.586	0.990(0.544 ~ 1.803)	0.975	0.862(0.431 ~ 1.722)	0.671
Q4	1.124(0.646 ~ 1.953)	0.677	1.164(0.689 ~ 1.967)	0.568	1.209(0.675 ~ 2.164)	0.520
CMI						
Q1	Ref		Ref		Ref	
Q2	1.540(0.807 ~ 2.939)	0.188	1.244(0.644 ~ 2.406)	0.513	1.852(0.896 ~ 3.828)	0.095
Q3	1.534(0.789 ~ 2.982)	0.205	1.161(0.581 ~ 2.321)	0.671	1.771(0.832 ~ 3.769)	0.137
Q4	2.010(0.991 ~ 4.074)	0.053	1.657(0.763 ~ 3.602)	0.200	2.219(0.942 ~ 5.228)	0.068
LAP						
Q1	Ref		Ref		Ref	
Q2	2.776(1.441 ~ 5.347)	0.003	1.778(0.894 ~ 3.536)	0.100	1.713(0.813 ~ 3.610)	0.155
Q3	1.952(1.075 ~ 3.544)	0.028	1.107(0.606 ~ 2.022)	0.739	1.250(0.616 ~ 2.535)	0.533
Q4	3.200(1.839 ~ 5.567)	<0.001	1.934(1.085 ~ 3.447)	0.026	2.046(1.010 ~ 4.145)	0.047
TyG						
Q1	Ref		Ref		Ref	
Q2	2.046(1.007 ~ 4.155)	0.048	1.371(0.676 ~ 2.780)	0.378	1.353(0.64 ~ 2.859)	0.425
Q3	1.809(0.965 ~ 3.390)	0.064	1.084(0.568 ~ 2.067)	0.805	1.228(0.575 ~ 2.623)	0.592
Q4	3.487(2.027 ~ 5.997)	<0.001	1.986(1.122 ~ 3.515)	0.019	2.082(1.016 ~ 4.269)	0.045
TyG-BMI						
Q1	Ref		Ref		Ref	
Q2	2.894(1.611 ~ 5.198)	<0.001	2.071(1.161 ~ 3.695)	0.014	2.291(1.234 ~ 4.252)	0.009
Q3	1.851(0.985 ~ 3.478)	0.056	1.300(0.690 ~ 2.452)	0.414	1.449(0.678 ~ 3.097)	0.335
Q4	1.921(1.086 ~ 3.400)	0.025	1.527(0.881 ~ 2.647)	0.131	1.632(0.820 ~ 3.246)	0.161
TyG-Waist						
Q1	Ref		Ref		Ref	
Q2	2.846(1.471 ~ 5.507)	0.002	1.777(0.885 ~ 3.566)	0.105	1.946(0.932 ~ 4.062)	0.076
Q3	2.486(1.440 ~ 4.293)	0.001	1.356(0.759 ~ 2.421)	0.301	1.669(0.835 ~ 3.334)	0.146
Q4	3.258(1.855 ~ 5.724)	<0.001	1.854(1.027 ~ 3.346)	0.041	2.035(0.949 ~ 4.364)	0.068
TyG-WHtR						
Q1	Ref		Ref		Ref	
Q2	3.172(1.545 ~ 6.512)	0.002	1.757(0.839 ~ 3.680)	0.134	1.550(0.706 ~ 3.405)	0.272
Q3	3.315(1.650 ~ 6.662)	<0.001	1.588(0.772 ~ 3.265)	0.206	1.713(0.757 ~ 3.874)	0.194
Q4	3.669(1.897 ~ 7.094)	<0.001	1.668(0.837 ~ 3.324)	0.145	1.557(0.693 ~ 3.501)	0.281
VAI						
Q1	Ref		Ref		Ref	
Q2	0.911(0.490 ~ 1.693)	0.767	0.712(0.387 ~ 1.311)	0.273	0.847(0.413 ~ 1.737)	0.647

(*continued on next page*)

Table 2 (*continued*)

	Model 1		Model 2		Model 3	
	OR (95CI%)	P	OR (95CI%)	P	OR (95CI%)	P
Q3	1.586(0.931 ~ 2.701)	0.089	1.021(0.605 ~ 1.723)	0.936	0.985(0.521 ~ 1.861)	0.962
Q4	2.244(1.473 ~ 3.419)	<0.001	1.131(0.663 ~ 1.931)	0.649	1.270(0.698 ~ 2.310)	0.430
Waist						
Q1	Ref		Ref		Ref	
Q2	0.893(0.508 ~ 1.572)	0.693	0.632(0.355 ~ 1.126)	0.118	0.810(0.454 ~ 1.447)	0.474
Q3	1.254(0.717 ~ 2.196)	0.425	0.737(0.413 ~ 1.316)	0.300	0.836(0.465 ~ 1.504)	0.546
Q4	1.334(0.780 ~ 2.281)	0.290	0.837(0.487 ~ 1.438)	0.516	0.929(0.521 ~ 1.654)	0.800
WHtR						
Q1	Ref		Ref		Ref	
Q2	2.845(1.499 ~ 5.402)	0.002	1.682(0.857 ~ 3.302)	0.129	1.500(0.765 ~ 2.942)	0.235
Q3	3.609(2.020 ~ 6.446)	<0.001	1.735(0.908 ~ 3.316)	0.095	1.594(0.770 ~ 3.298)	0.206
Q4	3.157(1.842 ~ 5.409)	<0.001	1.430(0.812 ~ 2.516)	0.213	1.396(0.740 ~ 2.633)	0.300
WWI						
Q1	Ref		Ref		Ref	
Q2	1.024(0.514 ~ 2.037)	0.947	0.660(0.324 ~ 1.343)	0.249	0.861(0.412 ~ 1.800)	0.688
Q3	1.275(0.696 ~ 2.336)	0.428	0.687(0.359 ~ 1.315)	0.255	0.923(0.472 ~ 1.805)	0.813
Q4	2.586(1.393 ~ 4.802)	0.003	1.094(0.563 ~ 2.126)	0.790	1.317(0.681 ~ 2.549)	0.410

Model 1 does not include covariates, Model 2 includes gender, age, education level, and race as covariates. Model 3 includes gender, age, education level, race, smoking and drinking as covariates.
BMI, Body mass index; LAP, lipid accumulation product index; NHANES, National Health and Nutrition Examination Survey; TyG, Triglyceride glucose; TyG-BMI, Triglyceride glucose-body mass index; TyG-Waist, Triglyceride glucose-waist circumference; TyG-WHtR, Triglyceride Waist-Stature Ratio; VAI, Visceral adiposity index; Waist, Waist circumference; WHtR Waist-to-Height Ratio; WWI, Weight-adjusted waist index.

L)), for female;(8)Waist = Waist circumference (cm);(9) WHtR = Waist (cm)/height (cm);(10) WWI = Waist (cm)/weight$^{1/2}$ (kg$^{1/2}$).

2.3. Statistical method

We categorized the obesity indexes into four groups. We applied weighted logistic regression to analyze the relationship between these indexes and the prevalence of GIC. Model 1 does not include covariates, while Model 2 includes gender, age, education level, and race as covariates. In Model 3, smoking and drinking are added to the covariates included in Model 2. Results were expressed as odds ratio (OR) and 95 % confidence intervals (CI). Subsequently, we identified the obesity index significantly linked to GIC, stratified it by age, gender, smoking or drinking, and conducted subgroup analysis. After that, we conducted a cohort analysis, and the data was provided by NHIS, and the follow-up time was until 2019. The Cox proportional hazards (COX) model was used to analyze the relationship between the obesity index and all-cause mortality of GIC patients. Gender, age, race, education level, smoking, and drinking were included as covariables. The result was expressed as an estimated hazard ratio (HR) and standard deviation (SD). We draw a survival analysis diagram to show the result. Then we used restricted cubic spline (RCS) to reveal the non-linear relationship between the obesity index and mortality. R was used for analysis in this study, and statistical significance was determined by p-value less than 0.05.

Table 3
Subgroup analysis of GIC with LAP and TyG in U.S. adults, NHANES 1999–2018.

	LAP		TyG	
	OR (95CI%)	P	OR (95CI%)	P
Male				
Q1	Ref		Ref	
Q2	1.173(0.475 ~ 2.901)	0.727	0.861(0.345 ~ 2.147)	0.746
Q3	0.854(0.383 ~ 1.903)	0.696	0.638(0.253 ~ 1.606)	0.337
Q4	1.389(0.559 ~ 3.454)	0.475	1.102(0.412 ~ 2.950)	0.845
Female				
Q1	Ref		Ref	
Q2	2.749(0.848 ~ 8.913)	0.091	2.642(0.825 ~ 8.463)	0.101
Q3	1.999(0.608 ~ 6.574)	0.251	2.775(0.900 ~ 8.561)	0.075
Q4	3.397(1.120 ~ 10.301)	0.031	4.808(1.695 ~ 13.643)	0.004
20–60				
Q1	Ref		Ref	
Q2	5.480(0.993 ~ 30.223)	0.051	0.568(0.114 ~ 2.837)	0.487
Q3	2.875(0.522 ~ 15.831)	0.222	0.927(0.197 ~ 4.350)	0.923
Q4	5.781(1.087 ~ 30.741)	0.040	1.031(0.223 ~ 4.778)	0.968
>60				
Q1	Ref		Ref	
Q2	1.362(0.618 ~ 3.003)	0.440	1.862(0.820 ~ 4.227)	0.136
Q3	1.098(0.503 ~ 2.398)	0.813	1.510(0.726 ~ 3.137)	0.267
Q4	1.773(0.827 ~ 3.804)	0.140	2.879(1.373 ~ 6.036)	0.006
Smoker				
Q1	Ref		Ref	
Q2	1.293(0.509 ~ 3.283)	0.586	0.752(0.304 ~ 1.860)	0.534
Q3	0.945(0.416 ~ 2.147)	0.892	0.722(0.254 ~ 2.053)	0.537
Q4	2.045(0.880 ~ 4.752)	0.096	1.514(0.627 ~ 3.659)	0.353
No-Smoker				
Q1	Ref		Ref	
Q2	2.621(0.704 ~ 9.759)	0.149	4.548(1.283 ~ 16.117)	0.019
Q3	1.952(0.508 ~ 7.502)	0.327	3.897(1.105 ~ 13.745)	0.035
Q4	2.038(0.582 ~ 7.139)	0.263	4.825(1.417 ~ 16.423)	0.012
Drinker				
Q1	Ref		Ref	
Q2	1.900(0.778 ~ 4.639)	0.157	1.004(0.417 ~ 2.418)	0.993
Q3	1.651(0.704 ~ 3.872)	0.246	1.216(0.514 ~ 2.878)	0.654
Q4	2.195(0.943 ~ 5.110)	0.068	1.687(0.738 ~ 3.855)	0.212
No-Drinker				
Q1	Ref		Ref	
Q2	1.359(0.352 ~ 5.249)	0.654	4.345(0.909 ~ 20.764)	0.065
Q3	0.568(0.145 ~ 2.225)	0.413	1.902(0.400 ~ 9.042)	0.415
Q4	1.774(0.523 ~ 6.017)	0.354	5.653(1.403 ~ 22.774)	0.015

Gender, age, race, education level, smoking, and drinking were included as covariables.
LAP, lipid accumulation product; NHANES, National Health and Nutrition Examination Survey; TyG, Triglyceride glucose.

3. Result

3.1. Participant information

A total of 21,411 participants were included in this study, including 187 patients with GIC. The median age of GIC group is 73.0 years old, while the average age of the control group is 50.0 years old. In both groups, male and female participants accounted for about 50 %. Among GIC patients, smokers and drinkers accounted for 60.4 % and 52.9 %. And in control group, smokers and drinkers accounted for 46.4 % and 59.6 %. Besides, the median follow-up time of GIC group and control group is 66 and 110 months. Details can be seen in Table 1.

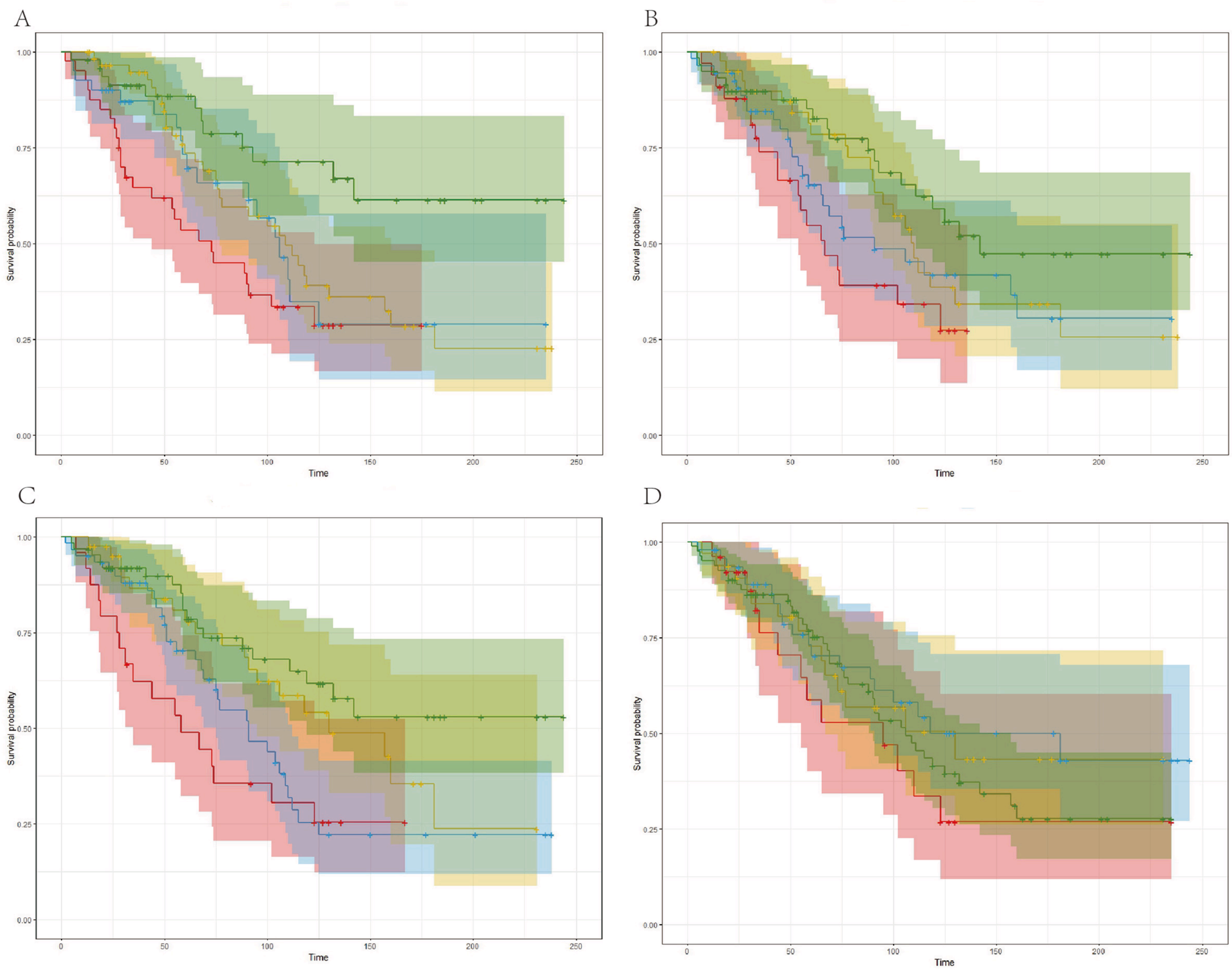

Fig. 1. Kaplan–Meier estimated survival curves of participants with GIC based on BMI(A), Waist(B), WHtR(C), and WWI(D) levels, NHANES 1999–2018. Each red, blue, yellow, green, line represents Q1, Q2, Q3, and Q4 of obesity indexes. BMI, Body mass index; GIC, Gastrointestinal cancers; NHANES, National Health and Nutrition Examination Survey; Waist, Waist circumference; WHtR, Waist-to-Height Ratio; WWI, Weight-adjusted waist index; (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.2. Weighted multiple logistic regression

We used weighted multiple logistic regression to analyze the cross-sectional relationship between ten obesity indexes and GIC. Model 1 does not include covariates, Model 2 includes gender, age, education level, and race as covariates. Model 3 includes gender, age, education level, race, smoking and drinking as covariates. Results showed that LAP, TyG, TyG-BMI, TyG-Waist, TyG-WHtR, VAI, WHtR, and WWI were significantly correlated with the prevalence of GIC in model 1. However, after adding covariates, LAP, TyG, and TyG-Waist have obvious relations with GIC in model 2. After considering more covariates, only LAP [Q4 vs Q1: OR (95CI%) = 2.046(:1.01 ~ 4.145), P = 0.047] and TyG [Q4 vs Q1: OR (95CI%) = 2.082(1.016 ~ 4.269), P = 0.045] were significantly correlated with GIC in model 3. Detail can be seen in Table 2.

3.3. Subgroup analysis

We further did a subgroup analysis for the indicators with significant differences in the previous analysis. Multiple weighted logistic regression is used and gender, age, race, education level, smoking, and drinking were included as covariables. Above results show LAP and TyG are related with GIC, so we took LAP and TyG for further study. Subgroup analysis was conducted according to age and sex, as well as smoking and drinking. The results showed that LAP was closely related to GIC in patients [Q4 vs Q1: OR (95CI%) = 3.397(1.120 ~ 10.301), P = 0.031] and patients aged < 60 [Q4 vs Q1: OR (95CI%) = 5.781(1.087 ~ 30.741), P = 0.040]. While TyG is significantly related to the prevalence of GIC in patients over 60[Q4 vs Q1: OR (95CI%) = 2.879 (1.373 ~ 6.036), P = 0.006], female [Q4 vs Q1: OR (95CI%) = 4.808 (1.695 ~ 13.643), P = 0.004] and patients who have not smoked [Q4 vs Q1: OR (95CI%) = 4.825(1.417 ~ 16.423), P = 0.012] or not drunk [Q4 vs Q1: OR (95CI%) = 5.653(1.403 ~ 22.774), P = 0.015]. In this study, multiple weighted logistic regression is used for analysis. We have not found a suitable method to analyze the interaction according to the weight. Therefore, we choose not to test interaction. The details are shown in Table 3.

3.4. Survival analysis

We conducted a cohort study and analyzed the relationship between obesity indexes and the death of GIC patients. According to the data from NHIS follow-up in 2019, there were 187 GIC patients. Gender, age, race, education level, smoking, and drinking were included as covariables. COX survival analysis showed that BMI [Q4 vs Q1: HR (95 %CI) = 0.369(0.176,0.773)], Waist [Q4 vs Q1: HR (95 %CI) = 0.381 (0.193,0.753)], WHtR [Q4 vs Q1: HR (95 %CI) = 0.416(0.209,0.831)],

Table 4
Survival analysis of obesity indexes and GIC in U.S. adults, NHANES 1999–2018.

	Q1	Q2[HR (95 %CI)]	Q3[HR (95 %CI)]	Q4[HR (95 %CI)]
BMI	Ref	0.681(0.389 ~ 1.994)	0.701(0.373 ~ 1.316)	0.369(0.176 ~ 0.773) **
CMI	Ref	1.026(0.503 ~ 2.096)	0.889(0.430 ~ 1.839)	0.764(0.375 ~ 1.556)
LAP	Ref	0.818(0.421 ~ 1.589)	0.862(0.423 ~ 1.755)	0.541(0.270 ~ 1.084)
TyG	Ref	1.664(0.785 ~ 3.526)	1.413(0.649 ~ 3.079)	1.296(0.631 ~ 2.661)
TyG-BMI	Ref	1.212(0.644 ~ 2.279)	0.804(0.402 ~ 1.609)	0.706(0.334 ~ 1.491)
TyG-Waist	Ref	1.030(0.479 ~ 2.216)	0.750(0.349 ~ 1.612)	0.671(0.311 ~ 1.448)
TyG-WHtR	Ref	0.898(0.437 ~ 1.846)	0.720(0.351 ~ 1.479)	0.576(0.265 ~ 1.253)
VAI	Ref	1.102(0.556 ~ 2.184)	0.966(0.471 ~ 1.983)	1.371(0.632 ~ 2.974)
Waist	Ref	0.531(0.275 ~ 1.024)	0.722(0.384 ~ 1.355)	0.381(0.193 ~ 0.753) **
WHtR	Ref	0.588(0.298 ~ 1.158)	0.839(0.448 ~ 1.570)	0.416(0.209 ~ 0.831) *
WWI	Ref	0.628(0.281 ~ 1.401)	0.412(0.191 ~ 0.887) *	0.403(0.188 ~ 0.864) *

Gender, age, race, education level, smoking, and drinking were included as covariables.
BMI, Body mass index; LAP, lipid accumulation product index; NHANES, National Health and Nutrition Examination Survey; TyG, Triglyceride glucose; TyG-BMI, Triglyceride glucose-body mass index; TyG-Waist, Triglyceride glucose-waist circumference; TyG-WHtR, Triglyceride Waist-Stature Ratio; VAI, Visceral adiposity index; Waist, Waist circumference; WHtR Waist-to-Height Ratio; WWI, Weight-adjusted waist index. * <0.05; ** <0.01; *** <0.001.

and WWI [Q4 vs Q1: HR (95 %CI) = 0.403(0.188,0.864)] were significantly related to the prognosis of GIC patients. Results showed that the higher the values of these indicators, the better the prognosis of patients. For the other six indicators, there was no statistical difference. The survival analysis chart and details can be seen in Fig. 1 and Table 4.

3.5. Restricted cubic spline

Above result show BMI, Waist, WHtR and WWI are related with prognosis of GIC. We take these four indexes for further analysis by RCS. Taking gender, age, race, education level, smoking, and drinking as covariables. Results showed that there was significant relationship between all-cause mortality and BMI ($P = 0.033$), Waist ($P = 0.034$) and WWI ($P = 0.045$), but not related with WHtR ($P = 0.062$). All of the effect did not conform to the nonlinear relationship ($P > 0.05$). Results are shown in Fig. 2.

4. Discussion

Previous prospective cohort studies have found that obesity-related markers are significantly related to the incidence of various cancers (Parra-Soto et al., 2021; Perez-Cornago et al., 2022; Recalde et al., 2021; Roos et al., 2024). In 2016 and 2020, according to the data in the European prospective investigation into cancer and nutrition study, researchers found that obesity has a significant impact on the incidence of colorectal cancer, esophageal cancer, and gastric cancer (Murphy et al., 2016; Sanikini et al., 2020). With the development and application of statistical technology, based on Mendelian randomization, researchers also found that obesity is closely related to the development of gastric cancer (Kim et al., 2023).

The results of weighted multiple logistic regression show that among the ten obesity indexes, TyG and LAP were the most closely related to the prevalence of GIC. Through subgroup analysis, we found that TyG is related to GIC in elderly patients, while LAP is related to GIC in non–elderly patients. Based on survival analysis, it was found that BMI, Waist and WWI are related to the prognosis of GIC patients.

In previous studies, TyG was used to predict the occurrence of diabetes and cardiovascular diseases. In recent years, some studies have also analyzed its predictive value for cancers (Cai et al., 2024; Kim et al., 2022; Liu et al., 2022; Okamura et al., 2020). It is consistent with the conclusion of this study, suggesting that TyG is closely related to the pathogenesis of GIC. On the other hand, this study found that TyG has a higher predictive value for GIC in elderly patients. This is similar to the conclusions of previous studies, and all suggest that TyG has a good application value in elderly patients (Zhang et al., 2023; Zhu et al., 2020).

LAP was first proposed as an index in 2009 to predict the cardiovascular risk of polycystic ovary syndrome (Wiltgen et al., 2009). Later research found that LAP also has a good predictive value for diabetes and hypertension (Fu et al., 2021; Wang et al., 2021). Shi analyzed 13,055 hypertensive patients and found that with the increase of LAP level, the risk of chronic kidney disease increased (Shi et al., 2022). In 2022, another study used the data analysis of NHANES from 2007 to 2016 and found that LAP, as an intermediary factor, completely mediated the relationship between diet and hyperuricemia (Wang et al., 2022). As far as we know, this study is one of the few studies to analyze the relationship between the incidence and prognosis of LAP and GIC, and we found that LAP is closely related to the incidence of GIC. It is suggested that LAP may also be used as a predictor of GIC.

Although many studies believe that obesity will reduce the survival time of cancer patients. However, other studies have come to the opposite conclusion. In 2018, a study of 1918 patients with metastatic melanoma found that under the same treatment conditions, obese patients had a higher survival time than normal patients (McQuade et al., 2018). A similar conclusion was reached in another study on the treatment of advanced non-small cell lung cancer (Kichenadasse et al., 2020). This may be due to the complex relationship between obesity index and mortality (Bhaskaran et al., 2018). However, due to the limited number of cases included in this study, it is difficult for us to analyze it further.

The mechanism of obesity on cancers has always been the focus of research. Previous studies have suggested that obesity may accelerate cancer growth by promoting the release of inflammatory factors (Kolb et al., 2016). A study in 2020 found that obesity can reduce the number of CD8 + T cells in the cancer microenvironment and their anti-cancer activity, thus accelerating the growth of cancers (Ringel et al., 2020). In another study, researchers found that there are legally aging cells in the cancer tissues of obese patients, suggesting that obesity may promote cancer growth by inducing cell aging (Fournier et al., 2023). In addition, it is found that insulin resistance can affect cancer cells through multiple signaling pathways, such as peroxisome proliferator-activated receptor gamma (Bogazzi et al., 2004). Obesity is closely related to insulin resistance, and the above mechanism may also be the mechanism of obesity acting on cancers. Generally speaking, the effect of obesity on cancers is complex and diverse.

There are also some limitations. First of all, NHANES can only provide data of a cross-section, this is a common problem in many NHANES studies (Hong et al., 2024; Sun et al., 2024). But we think that the obesity index can reflect the physical condition of participants in a period of time. In addition, most previous studies focused on body mass index and waist circumference, and this study included ten indicators to make the analysis more comprehensive. Second, limited by the number of samples and research design, it is difficult to further subgroup analysis. The purpose of this study is to provide preliminary evidence for more rigorous research settings in the future. Third, the number of patients is still small. A larger sample is still needed for analysis. Participants in the NHANES study are representative. As a remedial measure, we fully consider the weight in logistic regression.

Conclusion: Based on the findings of NHANES from 1999 to 2018, TyG and LAP are closely related to GIC, among which TyG is more related to elderly patients, while LAP is more related to middle-aged and young patients. The cohort study and RCS found that BMI, Waist, and

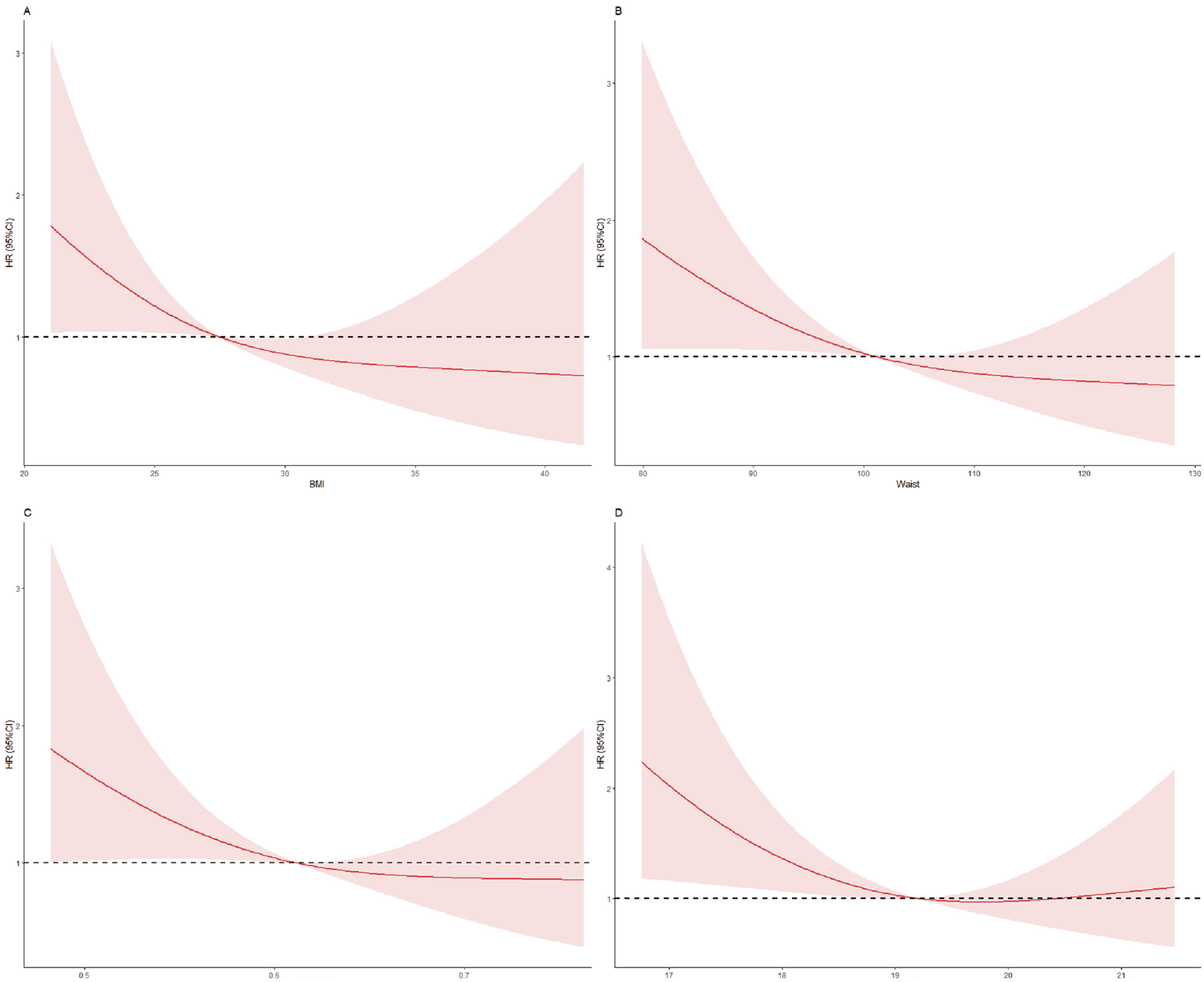

Fig. 2. Restricted cubic spline estimated survival curves of participants with GIC based on BMI(A), Waist(B), WHtR(C), and WWI(D) levels, NHANES 1999–2018. BMI, Body mass index; GIC, Gastrointestinal cancers; NHANES, National Health and Nutrition Examination Survey; Waist, Waist circumference; WHtR, Waist-to-Height Ratio; WWI, Weight-adjusted waist index;

WWI were significantly related to the prognosis of GIC patients.

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6. Ethics approval and consent to participate

This study uses NHANES data. The participants in this study provided consent, and the NCHS Research Ethics Review Board approved the study protocol. All participants had provided written, informed consent for the use of their data.

CRediT authorship contribution statement

Bowen Zha: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Angshu Cai:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Guiqi Wang:** Writing – review & editing, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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