Research article

Association between triglyceride-glucose index and sarcopenia in patients with chronic inflammatory airway disease

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ABSTRACT

Objective: This research sought to explore the association between the triglyceride-glucose (TyG) index and the risk of sarcopenia in patients with chronic inflammatory airway disease (CIAD).
Methods: Data were obtained from the National Health and Nutrition Examination Survey 2011–2018. Grouping was performed using TyG index tertiles and multiple logistic regression was employed to assess the correlation between TyG levels and the risk of sarcopenia. The Receiver Operating Characteristic (ROC) curve analysis was conducted to determine the prognostic value of the TyG index for sarcopenia. Linear regression analysis was utilized to elucidate the direct relationship between TyG index and sarcopenia. Additionally, the curve between the TyG and sarcopenia indices was examined using a generalized additive model.
Results: The study included 981 individuals diagnosed with CIAD. After adjusting for potential confounders, a significant positive correlation was observed between TyG and sarcopenia (OR = 1.70, 95 % CI: 1.20–2.39, P = 0.002). Trend analysis using the chi-square test revealed an increase in sarcopenia prevalence concomitant with higher TyG levels (P < 0.05). Furthermore, linear regression analysis revealed a notable inverse linear association between the TyG and sarcopenia indices (β = −0.03; 95 % CI: −0.07–0.01; P = 0.020). The ROC curves corroborated the robust predictive capacity of TyG for sarcopenia among patients with CIAD, with an AUC of 0.685 (95 % CI: 0.636–0.735, P < 0.001).
Conclusion: Our research indicates a positive association between TyG and sarcopenia in CIAD patients. The TyG index may serve as a reliable marker for predicting sarcopenia risk in CIAD patients.

1. Introduction

Chronic Inflammatory Airway Diseases (CIAD), encompassing conditions such as chronic obstructive pulmonary disease (COPD), asthma, and chronic bronchitis, significantly affect the global burden of non-communicable diseases. Current estimates suggest that approximately 544.9 million individuals worldwide are affected by chronic respiratory conditions, with an increasing trend [1]. These conditions are the third leading cause of death globally, after cardiovascular diseases and cancer [2]. CIAD has attracted increased attention because of the growing burden associated with multiple extrapulmonary complications that gradually contribute to

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disabilities [3,4]. Sarcopenia affects the functional capacity [4]. The prevalence of sarcopenia among individuals with COPD ranges from 8 to 63 %, depending on the diagnostic approach, applied criteria, and demographics under investigation [5]. Moreover, research has revealed that sarcopenia is independently linked to many negative outcomes of chronic respiratory diseases, such as physical disability, poor quality of life, reduced independence in activities of daily living, and increased mortality [6–8].

Furthermore, investigations have established the involvement of low-grade systemic inflammation and insulin resistance and in the pathogenesis of sarcopenia [9,10]. Epidemiological studies have reported the frequent co-occurrence of sarcopenia with metabolic dysfunctions, including hypertension, dyslipidemia, and type 2 diabetes [11,12]. Clinical and basic studies have indicated that CIAD is independently associated with IR [13,14], suggesting that IR may act as a pivotal link in the onset of sarcopenia among patients with CIAD.

The triglyceride-glucose (TyG) index is a readily obtainable indicator for both IR and systemic inflammation, with evidence supporting its predictive relevance for various IR-associated pathologies [15–17]. Contemporary research has identified a substantial link between the TyG index and respiratory diseases [18,19]. Nonetheless, the association between sarcopenia and TyG index prevalence in CIAD patients remains to be elucidated. This research aimed to validate the linkage between sarcopenia and TyG index manifestations in CIAD patients.

2. Materials and methods

2.1. Study design and data source

In this cross-sectional study, data were drawn from the National Health and Nutrition Examination Survey (NHANES), which employs a complex, stratified sampling methodology to provide a nationally representative overview of the health and nutritional status of the U.S. population. The dataset, which is accessible via NHANES, encompasses comprehensive details on health, nutrition, and behavioral patterns. Ethical approval for the NHANES data was granted by the National Center for Health Statistics Research Ethics Review Board, accompanied by informed consent from all subjects. The Institutional Review Board determined that further ethical clearance was unnecessary due to the public domain status of the NHANES data.

This study used data spanning four NHANES cycles between 2011 and 2018, encompassing 39,156 individuals. Participant selection was meticulously narrowed down to align with the specified research goals. Participants were excluded if they lacked data on triglycerides, fasting blood glucose (FBG, n = 27475), body mass index (BMI, n = 22), appendicular skeletal muscle mass (ASM, n = 5071), or other variables (n = 84); were aged ≤18 years (n = 1349); or had non-chronic airway inflammatory diseases (n = 4174). Fig. 1 shows a detailed flowchart of the participant selection process.

2.2. Muscle mass

Muscle mass was quantified using ASM as a measure, denoted in grams, encompassing the combined lean soft tissue mass of both the upper and lower extremities, ascertained via Dual-energy X-ray absorptiometry. BMI was derived using the ratio of weight to the square of height (kg/m^2). The ASM/BMI ratio, known as the sarcopenia index, is an indicator of muscle mass. The Foundation for the National Institutes of Health (FNIH) Sarcopenia Project [20,21] adopted the following criteria to identify participants with sarcopenia: a sarcopenia index below 0.789 for men and below 0.512 for women.
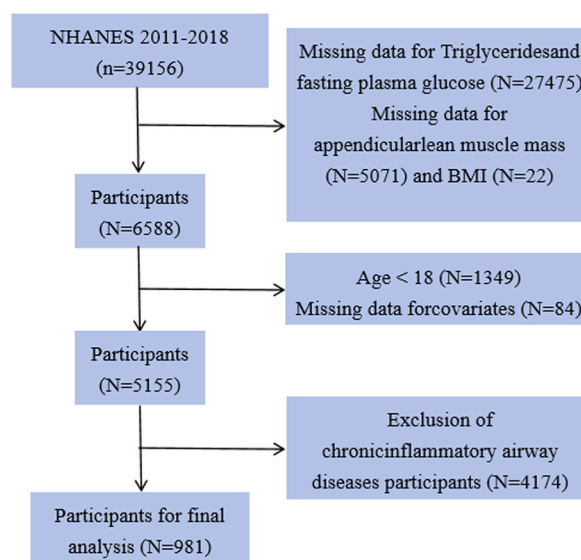

Fig. 1. Flow chart of the participant selection process.

2.3. Evaluation of CIAD

In this investigation, CIAD encompassed conditions such as asthma, chronic bronchitis, and COPD, as self-reported by the participants. Consistent with previous research [22], NHANES required respondents to indicate whether a physician had diagnosed them with any of the aforementioned ailments. Affirmative responses categorized individuals as afflicted with these conditions.

2.4. Diagnostic criteria for diabetes

Diabetes was diagnosed when any of the following criteria were met: (1) confirmation of diabetes by a medical professional; (2) glycated hemoglobin (HbA1c) levels exceeding 6.5 %; (3) fasting plasma glucose levels of 7.0 mmol/L or above; (4) random plasma glucose levels surpassing 11.1 mmol/L; (5) Oral Glucose Tolerance Test yielding glucose levels greater than 11.1 mmol/L within 2 h.

2.5. Hypertension diagnosis

Hypertension diagnosis adhered to established parameters, confirmed upon meeting any of the subsequent conditions: (1) self-reporting of elevated blood pressure or antihypertensive medication usage; and (2) diastolic blood pressure of 80 mmHg or above, or systolic blood pressure of 130 mmHg or above, following the 2017 AHA/ACC Guidelines for Hypertension Monitoring and Diagnosis.

2.6. Data collection

Variables for this investigation were sourced from the NHANES database and included demographic details, confounding variables, and laboratory results. Demographics included sex (male or female), age, ethnicity (non-Hispanic black, non- Mexican American, Hispanic white, other Hispanic, or others), and educational attainment (less than high school, high school graduate, or higher). Smoking status was categorized as "never" (not exceeding 100 cigarettes in a lifetime), "former" (exceeding 100 cigarettes, ceased prior to the survey), or "current" (exceeding 100 cigarettes, smoked intermittently), also constituted confounding variables.

Table 1
Weighted characteristics of the study population based on the tertiles of the TyG index.

	All	TyG 1 (<8.15)	TyG 2 (8.15–8.75)	TyG 3 (>8.75)	P-value
Age (years)	38.12 ± 12.94	32.97 ± 12.72	37.73 ± 12.54	42.77 ± 11.76	<0.001
Gender (n, %)					0.015
Male	452 (46.1)	135 (41.6)	139 (42.5)	178 (54.1)	
Female	529 (53.9)	190 (58.4)	188 (57.5)	151 (45.9)	
Ethnicity (n, %)					<0.001
Mexican American	66 (6.7)	19 (5.7)	26 (7.8)	21 (6.3)	
Other Hispanic	62 (6.3)	16 (5.0)	24 (7.2)	22 (6.5)	
Non-Hispanic White	649 (66.2)	190 (58.4)	221 (67.6)	238 (72.8)	
Non-Hispanic Black	122 (12.3)	70 (21.6)	32 (9.7)	20 (6.2)	
Other race	84 (8.5)	30 (9.3)	26 (7.7)	28 (8.2)	
Education level (n, %)					
Below high school	155 (15.8)	42 (12.8)	58 (17.5)	55 (16.8)	0.417
High school	257 (26.2)	94 (29.1)	82 (24.9)	81 (24.7)	
Above high school	539 (55.0)	189 (58.1)	157 (57.6)	193 (58.5)	
BMI (kg/m^2)	29.4 ± 7.27	26.80 ± 7.06	29.21 ± 7.18	31.79 ± 6.73	<0.001
Smoking (n, %)					<0.001
Never	464 (47.3)	189 (58.2)	161 (49.2)	114 (34.7)	
Former	212 (21.6)	59 (18.2)	67 (20.6)	86 (26.1)	
Now	305 (31.1)	77 (23.6)	99 (30.2)	129 (39.2)	
ALT (U/L)	25.66 ± 18.57	20.26 ± 12.90	24.49 ± 15.96	31.34 ± 22.95	<0.001
AST (U/L)	24.55 ± 12.98	22.36 ± 10.21	24.27 ± 14.08	26.64 ± 13.53	0.002
Scr (mmol/L)	75.01 ± 17.32	74.49 ± 16.77	74.30 ± 16.59	76.16 ± 18.40	0.309
TC (mg/dl)	188.70 ± 41.88	168.00 ± 34.83	187.12 ± 34.07	207.35 ± 45.73	<0.001
TG (mg/dl)	121.38 ± 96.09	53.10 ± 12.91	94.81 ± 18.33	204.41 ± 119.17	<0.001
LDL-C (mg/dl)	113.24 ± 37.47	96.88 ± 30.81	115.43 ± 30.66	124.89 ± 43.63	<0.001
HDL-C (mg/dl)	51.70 ± 15.01	60.53 ± 16.85	52.71 ± 12.82	43.41 ± 10.22	<0.001
FPG (mg/dl)	105.46 ± 32.86	94.35 ± 8.78	99.41 ± 13.16	120.69 ± 49.48	<0.001
HbA1c (%)	5.60 ± 1.04	5.27 ± 0.36	5.44 ± 0.60	6.03 ± 1.51	<0.001
Diabetes mellitus (n, %)	96 (9.8)	4 (1.24)	14 (4.18)	78 (23.71)	<0.001
HT (n, %)	296 (30.2)	73 (22.4)	88 (27.0)	135 (40.9)	<0.001
Sarcopenia (n, %)	90 (9.2)	9 (2.9)	28 (8.6)	53 (16.1)	<0.001

All values are presented as proportion (%), or mean ± standard deviation.
ALT, alanine transaminase; AST, aspartate transaminase; Scr, Serum Creatinine; BMl, body mass index; HT, Hypertension; TC, Total Cholesterol; TG, Triglycerides; LDL-C, Low-Density Lipoprotein Cholesterol; HDL-C, High-Density Lipoprotein Cholesterol; FPG, fasting plasma glucose; HbA1c, glycated haemoglobin.

Laboratory metrics included alanine aminotransferase (ALT), serum creatinine (Scr), triglycerides (TG), total cholesterol (TC), aspartate aminotransferase (AST), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), FBG, and HbA1c, procured via automated hematological analyzers.

2.7. Statistical methods

Statistical analyses utilized R software (version 4.0.1) and EmpowerStats, incorporating sample weights to address the complex multistage probabilistic sampling of the NHANES dataset. Continuous variables were expressed as mean ± standard deviations, and categorical variables as percentages. The study cohort was stratified according to the TyG index quantiles. Weighted analysis of variance (ANOVA) was utilized to assess continuous variable disparities across tripartite groups, complemented by weighted chi-square tests for categorical counterparts. Logistic regression, both univariate and multivariate, was utilized to investigate the linkage between the TyG index and sarcopenia. Model 1 was unadjusted. Model 2 incorporated adjustments for sex, age, ethnicity, and smoking. Model 3 included these factors plus ALT, AST, Scr, TC, LDL, HDL, diabetes mellitus, and hypertension. Receiver Operating Characteristic (ROC) curve analysis gauged the predictive capacity of the TyG index for sarcopenia. Additionally, linear regression, in both univariate and multivariate forms, appraised the linear association between the TyG index and sarcopenia metrics. A generalized additive model delineated the dose-response curve relating the TyG index to the sarcopenia metric with sex (male/female), age (<40/≥40), BMI (<25/≥25), diabetes mellitus (yes/no), and hypertension (yes/no) based subgroup analyses. Statistical significance was attributed to two-sided P-values of <0.05.

3. Results

3.1. Baseline characteristic

Adhering to the predefined screening criteria, 981 individuals from the 2011 to 2018 NHANES database were included. The clinical profiles of the patients are presented in Table 1. Based on the TyG quantiles, participants were categorized into the TyG1 group (TyG <8.15, n = 325 (33.1 %)), TyG2 group (8.15≤TyG≤8.75, n = 327 (33.3 %)) and the TyG3 group (TyG >8.75, n = 329 (33.5 %)). Higher TyG indices corresponded to a decline in the percentage of female subjects and HDL-C levels, whereas there was an increase in age, male subject ratio, BMI, smoker ratio, ALT, AST, TC, LDL-C, TG, FBG, HbA1c, as well as the prevalence of diabetes, hypertension, and sarcopenia (P < 0.05). There were no significant differences in education level and Scr values between the groups (P > 0.05).

3.2. Association between TyG and the risk of sarcopenia

Table 2 shows the correlation between the TyG index and sarcopenia in the subjects. Regression analyses revealed a consistent positive linkage between the TyG index and sarcopenia in both the unadjusted and fully adjusted models. The unadjusted model (Model 1) presents an elevated sarcopenia risk by a factor of 2.33 with each TyG unit increment (OR = 2.33, 95%CI: 1.78–3.05, p < 0.001). Post-multivariate adjustments, a one-unit TyG rise was linked to an 89 % (Model 2, OR = 1.89, 95 % CI: 1.41–2.54, p < 0.0001) and 70 % (Model 3, OR = 1.7, 95 % CI: 1.20–2.39, p < 0.0001) elevation in sarcopenia risk, respectively (Table 2).

Subsequently, the TyG index was categorized into tertiles, with the first quantile serving as a reference in the logistic analyses. The Model 3 indicated that subjects in the second and third TyG tertiles had an elevated risk of sarcopenia compared to the first tertile (second tertile: OR = 2.65, 95%CI: 1.30–5.43, p = 0.007; third tertile: OR = 3.16, 95%CI: 1.51–6.62, p = 0.002) (Table 2). Additionally, a trend chi-square analysis was used to confirm that higher TyG levels can be used to predict an increased incidence of sarcopenia (P for trend <0.05).

3.3. Correlation between TyG index and sarcopenia index

Univariate and multivariate linear regression analyses indicated a negative linkage between TyG and sarcopenia indices. The

Table 2
Weighted multivariate logistic regression of the association between TyG index and sarcopenia.

Variables	Model 1		Model 2		Model 3	
	OR (95%CI)	P	OR (95%CI)	P	OR (95%CI)	P
TyG	2.33 (1.78–3.05)	<0.001	1.89 (1.41–2.54)	<0.001	1.70 (1.20–2.39)	0.002
Q1	1 (Ref.)		1 (Ref.)		1 (Ref.)	
Q2	3.64 (1.82–7.27)	<0.001	2.69 (1.33–5.47)	0.006	2.65 (1.30–5.43)	0.007
Q3	6.24 (3.21–12.12)	<0.001	3.85 (1.92–7.72)	<0.001	3.16 (1.51–6.62)	0.002
P for trend	<0.001					

Model 1 was adjusted for no covariates.
Model 2 was adjusted for gender, age, ethnicity, and smoking.
Model 3 was adjusted for gender, age, ethnicity, smoking, ALT, AST, Scr, TC, LDL, HDL, HP and DM. ALT, alanine transaminase; AST, aspartate transaminase; Scr, Serum Creatinine; TC, Total Cholesterol; LDL, Low-Density Lipoprotein; HDL, High-Density Lipoprotein; DM, diabetes mellitus.

unadjusted model reveals a 0.04-unit decrement in the sarcopenia index with each unit increment of the TyG index ($\beta = -0.04$; 95 % CI, −0.06 to −0.03; P < 0.001). Even after adjustment for confounding factors, the link between the TyG index and the sarcopenia index retains significance ($\beta = -0.03$; 95 % CI, −0.07 to −0.01; P = 0.020) (Table 3).

Generalized additive modeling and smoothed curve fitting were employed to investigate the linkage between the TyG and sarcopenia indices. The analysis revealed a negative linear correlation between the two indices (Fig. 2). Moreover, this linear relationship persisted even after grouping patients according to sex, age, BMI, smoking status, diabetes mellitus, and hypertension (Fig. 3A–E).

3.4. ROC analysis of TyG index

ROC curves were employed to assess the predictive value of TyG levels for sarcopenia in patients with CIAD. Fig. 4 demonstrates that the AUC of TyG was 0.685 (95%CI: 0.636–0.735, P < 0.001), with a cutoff value of 8.455, yielding a sensitivity of 77.6 % and a specificity of 53.3 % (Table 4). To assess the accuracy of the predictive model, a calibration plot was generated, followed by the execution of the Hosmer–Lemeshow test (refer to Fig. S1). The outcomes of the test indicated a strong alignment between the predicted and observed probabilities (p-value = 0.112). These findings indicate that the TyG index could be a reliable predictor of sarcopenia in CIAD patients.

4. Discussion

Chronic inflammatory airway disease is a complex condition that causes respiratory dysfunction as well as coexists with other systemic diseases, such as cardiovascular diseases, metabolic disorders, and osteoporosis [23–25]. Extensive studies have revealed a high risk of sarcopenia in chronic respiratory diseases patients [26–28]. A meta-analysis conducted by Benz et al. [5] indicated a 21.6 % prevalence of sarcopenia in patients with COPD. Notably, sarcopenia adversely affects CIAD, diminishes patient quality of life, increases hospital admissions and mortality rates, and amplifies societal healthcare costs. Jones et al. [29] revealed that sarcopenia in patients with COPD correlated with aggravated airflow limitation, decreased physical activity, and diminished functional and exercise capacities. Hu et al. [30] found an association between increasing sarcopenia with a surge in asthma symptomatology, with severe sarcopenia markedly increasing airway constriction risk and curtailing peak expiratory flow. Hence, further research is required to explore indicators linked to sarcopenia in patients with CIAD. This research evaluated the association between the TyG index and the risk of sarcopenia in this demographic group. Our results demonstrate a positive linkage between the TyG index and sarcopenia. Specifically, the risk of muscle mass loss escalates markedly with higher TyG index values, where each unit increase in the TyG index is linked to a 0.04 unit reduction in the muscle mass index. Moreover, the TyG index exhibits predictive potential for muscle mass loss in patients with CIAD, with an AUC of 0.685, indicating its reliability as a biomarker. This study provides clinicians with a crucial tool for the early detection of sarcopenia risk in patients with chronic airway diseases. Regular monitoring of the TyG index, coupled with comprehensive patient assessments, can enable early intervention in sarcopenia cases, thereby improving patient health outcomes and quality of life.

Chronic inflammatory airway disease is a systemic condition that increases the risk of IR-related diseases [31]. IR in patients with CIAD may be associated with systemic inflammation and oxidative stress. Watz et al. [32] revealed notably elevated levels of sensitive IL-6 and C-reactive protein in CIAD patients with metabolic syndrome relative to those without the condition. Bolton et al. [33] reported increased IR levels in patients with COPD. Notably, a strong correlation exists between IR and sarcopenia, characterized by skeletal muscle comprising 40–50 % of adult lean body mass and serving as the principal site for insulin-mediated glucose metabolism [34]. Therefore, muscle mass is a critical factor in regulating the glucose and energy balance and is influenced by the equilibrium of protein synthesis and degradation within tissues. In addition, diminished insulin sensitivity is linked to atypical adipogenesis and augmented intramuscular lipid accumulation. This creates an imbalance between visceral fat proliferation and muscular degeneration, ultimately leading to sarcopenia [35]. Epidemiological evidence corroborates this link, with sarcopenia manifesting in up to 18 % of type 2 diabetes mellitus patients [36]. A meta-analysis [37] of 13 cross-sectional studies involving 35,581 middle-aged and elderly non-obese individuals revealed a 36.45 % incidence of metabolic syndrome (Met-S) among those with sarcopenia, underscoring a positive correlation with Met-S. The TyG index functions as a marker of IR and metabolic anomalies, demonstrating efficacy in addressing a spectrum of metabolic and inflammatory conditions [38,39]. Previous research has primarily examined the correlation between TyG levels as well as metabolic and cardiovascular diseases. A meta-analysis [40] suggests that individuals with elevated TyG indices are at an increased risk of heart failure and coronary artery disease. Moreover, a heightened TyG index correlates with the severity of coronary artery disease and a negative prognosis in affected patients [41]. Additional investigations [42] have identified that the relative risk for chronic kidney disease in patients with the highest TyG index is 1.47 (95 % CI: 1.32–1.63). Studies [43,44]

Table 3
Linear regression analysis of TyG index and sarcopenia index.

	Non-adjusted model			Adjusted model		
	β	95%CI	P	β	95%CI	P
TyG	−0.04	−0.06−−0.03	<0.001	−0.03	−0.07–−0.01	0.020

Non-adjusted model was adjusted for no covariates. Adjusted model was adjusted for gender, age, ethnicity, smoking, ALT, AST, Scr, TC, LDL, HDL, HP, and DM. ALT, alanine transaminase; AST, aspartate transaminase; Scr, Serum Creatinine; TC, Total Cholesterol; LDL, Low-Density Lipoprotein; HDL, High-Density Lipoprotein; DM, diabetes mellitus.
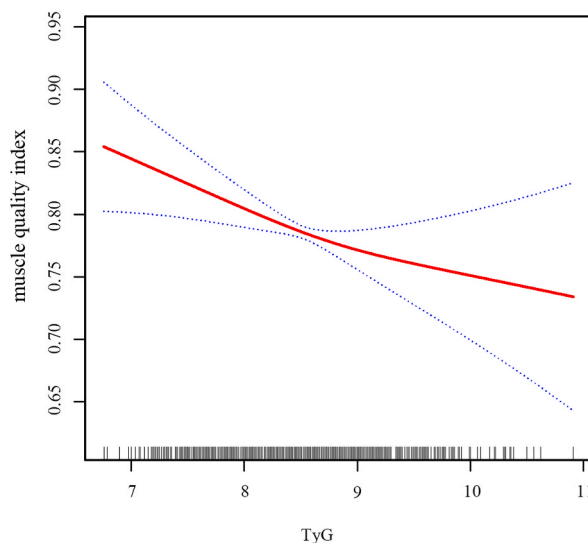
Fig. 2. Smooth curve fitting for TyG and sarcopenia. The area between the upper and lower blue dashed lines represents 95 % CI.

have elucidated a notable association between an elevated TyG index and a heightened risk of obstructive sleep apnea and depression. Investigations have also revealed a correlation between CIAD and TyG. Wu et al. [18] utilized the NHANES dataset to assess the relationship between the TyG index and chronic lung disease, respiratory symptoms, and lung function. Their analysis revealed a significant association between elevated TyG levels and an increased likelihood of diagnosing sputum production, cough, exertional dyspnea, wheezing, and chronic bronchitis. Moreover, a linkage was observed between TyG and an elevated relative risk of restrictive spirometry patterns. Subsequent findings from a longitudinal study [45] indicated that more than a median follow-up period of 31 years, the TyG index consistently predicted future COPD incidence, even when adjusted for known confounders, albeit with notable sex-specific variations. Furthermore, a robust correlation was identified between sarcopenia and the TyG index. An analysis involving 15,741 non-diabetic individuals revealed an independent and inverse linkage between the TyG index and skeletal muscle mass index [19]. Consistent with previous research, Aligning with prior studies, these findings confirm that TyG is an independent predictor of sarcopenia onset in CIAD patients. Moreover, ROC curve validated the predictive accuracy of TyG for the onset of sarcopenia. Extended linear regression analyses further confirmed a substantial inverse linear relationship between TyG and muscle mass index, persisting across sex (male/female), age ($<40/\geq40$), BMI ($<25/\geq25$), diabetes mellitus (yes/no), and hypertension (yes/no).

A previous study [22] found that patients with sarcopenia and COPD had overweight BMIs. Similarly, our baseline table showed that the BMI of the included population was in the overweight range, likely due to reduced physical activity from chronic airflow obstruction in patients with CIAD. Although this study adjusted for BMI using regression analysis, additional extensive research was needed to explore the impact of BMI on outcomes. Moreover, our study also revealed a positive linkage between higher TyG levels and the prevalence of hypertension and diabetes in patients with CIAD, which further confirmed the stability of TyG.

4.1. Strengths and limitations

There are several advantages to this study. Our study is based on the NHANES database, and all variables were collected in a standardized and homogeneous manner, ensuring the reliability of the results. In addition, the statistical analysis incorporated the appropriate NHANES sample weights and employed covariate adjustment to minimize the impact of confounding variables, thereby enhancing the credibility and generalizability of the results. Nevertheless, it is important to recognize certain limitations of our study. First, the cross-sectional study design precludes inferring causality, and the findings indicate only a correlation between the TyG index and sarcopenia in CIAD patients, rather than a causal relationship. Second, the diagnosis of CIAD was based on self-report questionnaires, which are more prone to bias and should therefore be interpreted with caution. Third, we did not further differentiate between CIAD (chronic bronchitis, asthma, and COPD) owing to sample size constraints. Whether there are differences in the associations between TyG and different types of diseases requires further investigation. Fourth, as with other observational epidemiological studies, unaccounted confounders may have influenced the outcomes. Finally, the study primarily assessed the predictive effect of a single indicator and did not distinguish between the modeling and validation groups. Consequently, more prospective research is necessary to confirm the predictive capability of the TyG index concerning sarcopenia risk in CIAD patients.

5. Conclusion

In conclusion, an examination of 981 CIAD cases from the four NHANES (2011–2018) revealed a link between the TyG index and sarcopenia within this group. These results underscore the significance of integrating the TyG index into standard clinical protocols as
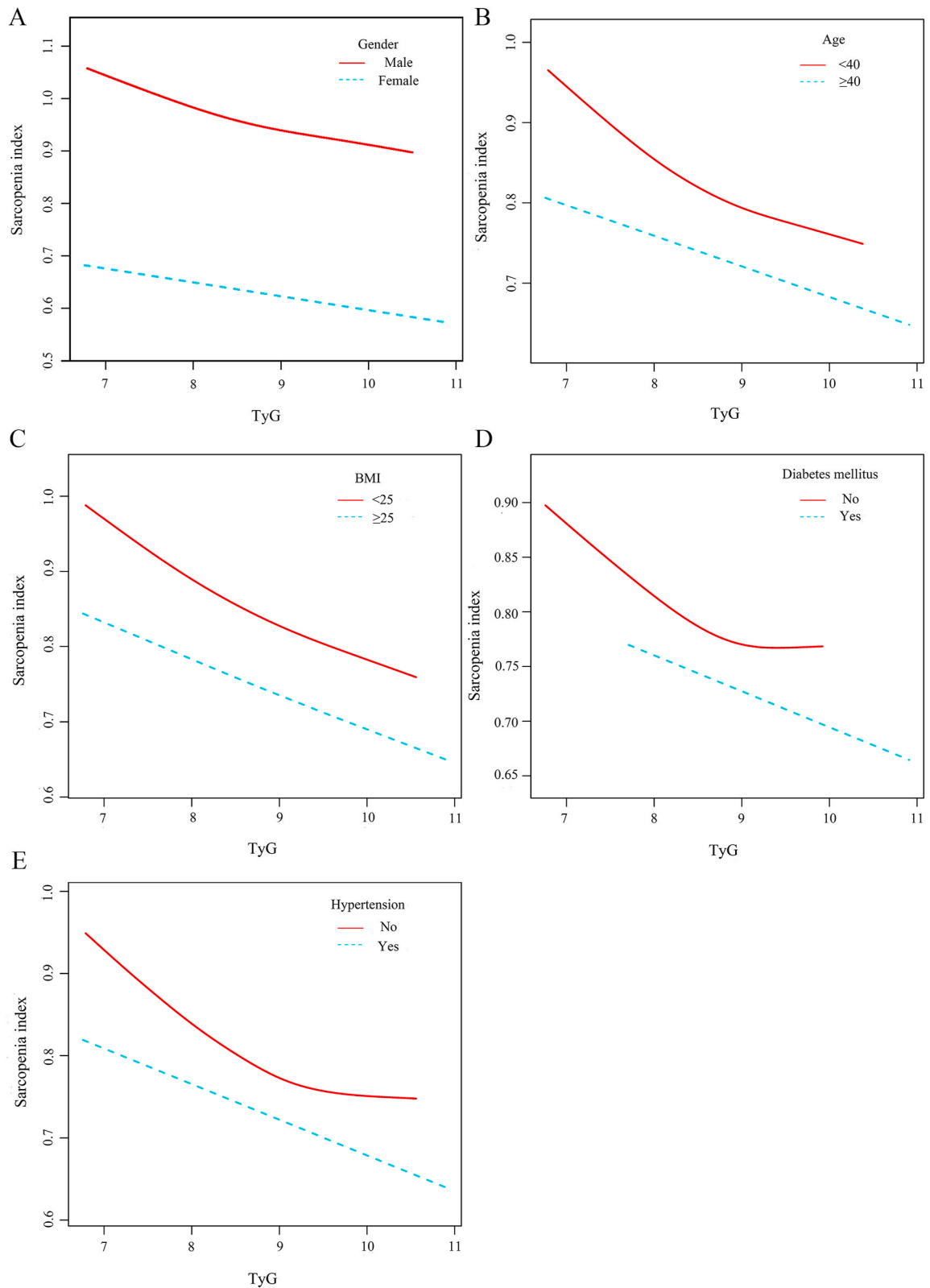
Fig. 3. Smooth curve fitting for TyG and sarcopenia based on sex (male/female) (A), age ($<40/\geq40$) (B), BMI ($<25/\geq25$) (C), diabetes mellitus (yes/no) (D), and hypertension (yes/no) (E). The area between the upper and lower blue dashed lines represents 95%CI.
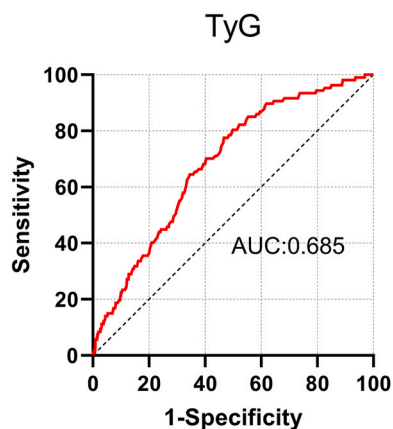
TyG

Fig. 4. Receiver operating characteristic curve analysis for predicting sarcopenia.

Table 4
Receiver operating characteristic (ROC) curve analysis of the predictive ability of TyG for sarcopenia.

Variable	AUC	95 % CI	Cut-of value	Sensitivity (%)	Specifcity (%)
TyG	0.685	0.636–0.735	8.455	77.6	53.3

an indicator for evaluating the risk of sarcopenia in CIAD patients.

Ethics approval and consent to participate

Ethical approval was not provided for this study on human participants because each participator provided written informed agreement before inclusion in the NHANES database, which was examined and allowed by the National Center for Health Statistics Ethics Review Board.

Data availability statement

This study uses data from a free and open public database, which can be found here: www.cdc.gov/nchs/nhanes/.

CRediT authorship contribution statement

Xinping Yang: Writing – review & editing, Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Lifang Li:** Writing – original draft, Data curation. **Ruina Li:** Writing – original draft, Data curation. **Pingping Li:** Writing – review & editing. **Hui Zhao:** Software, Methodology, 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.

Abbreviations

ASMI   appendicular skeletal muscle mass index
ALT   Alanine aminotransferase

AST   Aspartate aminotransferase
CIAD   Chronic Inflammatory Airway Diseases
COPD   chronic obstructive pulmonary disease
DM   Diabetes mellitus
FBG   fasting blood glucose
HDL-C: High density lipoprotein cholesterol
HT   Hypertension
IR   Insulin resistance
LDL-C: Low-density lipoprotein cholesterol
NHANES   National Health and Nutrition Examination Survey
Scr   Serum creatinine
TC   Total cholesterol
TG   Triglyceride
TyG   Triglycerides-glucose index

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e34194.

References

[1] Collaborators Gbdcrd, Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017, Lancet Respir. Med. 8 (6) (2020) 585–596.

[2] Collaborators Gbdcrd, Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015, Lancet Respir. Med. 5 (9) (2017) 691–706.

[3] Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015, Lancet Respir. Med. 5 (9) (2017) 691–706.

[4] A.E. Bone, N. Hepgul, S. Kon, M. Maddocks, Sarcopenia and frailty in chronic respiratory disease, Chron. Respir. Dis. 14 (1) (2017) 85–99.

[5] E. Benz, K. Trajanoska, L. Lahousse, J.D. Schoufour, N. Terzikhan, E. De Roos, G.B. de Jonge, R. Williams, O.H. Franco, G. Brusselle, F. Rivadeneira, Sarcopenia in COPD: a systematic review and meta-analysis, Eur. Respir. Rev. 28 (154) (2019).

[6] K. Marquis, R. Debigaré, Y. Lacasse, P. LeBlanc, J. Jobin, G. Carrier, F. Maltais, Midthigh muscle cross-sectional area is a better predictor of mortality than body mass index in patients with chronic obstructive pulmonary disease, Am. J. Respir. Crit. Care Med. 166 (6) (2002) 809–813.

[7] A.Y. Leem, Y.S. Kim, K.S. Chung, M.S. Park, Y.A. Kang, Y.M. Park, J.Y. Jung, Sarcopenia is associated with cardiovascular risk in men with COPD, independent of adiposity, Respir. Res. 23 (1) (2022) 185.

[8] J.A. Hwang, Y.S. Kim, A.Y. Leem, M.S. Park, S.K. Kim, J. Chang, J.Y. Jung, Clinical Implications of sarcopenia on decreased Bone density in men with COPD, Chest 151 (5) (2017) 1018–1027.

[9] H. Nishikawa, A. Asai, S. Fukunishi, S. Nishiguchi, K. Higuchi, Metabolic syndrome and sarcopenia, Nutrients 13 (10) (2021).

[10] M.E. Cleasby, P.M. Jamieson, P.J. Atherton, Insulin resistance and sarcopenia: mechanistic links between common co-morbidities, J. Endocrinol. 229 (2) (2016). R67-81.

[11] A. Izzo, E. Massimino, G. Riccardi, G. Della Pepa, A narrative review on sarcopenia in type 2 diabetes mellitus: prevalence and associated factors, Nutrients 13 (1) (2021).

[12] A.J. Cruz-Jentoft, A.A. Sayer, Sarcopenia, Lancet 393 (10191) (2019) 2636–2646.

[13] F.V.C. Machado, F. Pitta, N.A. Hernandes, G.L. Bertolini, Physiopathological relationship between chronic obstructive pulmonary disease and insulin resistance, Endocrine 61 (1) (2018) 17–22.

[14] J.P. Allinson, P.H. Patel, G.C. Donaldson, Obesity, insulin resistance, and asthma, Am. J. Respir. Crit. Care Med. 206 (9) (2022) 1057–1058.

[15] J. Alizargar, C.H. Bai, N.C. Hsieh, S.V. Wu, Use of the triglyceride-glucose index (TyG) in cardiovascular disease patients, Cardiovasc. Diabetol. 19 (1) (2020) 8.

[16] Z. Qin, J. Zhao, J. Geng, K. Chang, R. Liao, B. Su, Higher triglyceride-glucose index is associated with increased likelihood of kidney stones, Front. Endocrinol. 12 (2021) 774567.

[17] Y. Liao, R. Zhang, S. Shi, Y. Zhao, Y. He, L. Liao, X. Lin, Q. Guo, Y. Wang, L. Chen, W. Li, S. Li, K. Chen, Y. Fang, Triglyceride-glucose index linked to all-cause mortality in critically ill patients: a cohort of 3026 patients, Cardiovasc. Diabetol. 21 (1) (2022) 128.

[18] T.D. Wu, A. Fawzy, E. Brigham, M.C. McCormack, I. Rosas, D.T. Villareal, N.A. Hanania, Association of triglyceride-glucose index and lung health: a population-based study, Chest 160 (3) (2021) 1026–1034.

[19] S.H. Ahn, J.H. Lee, J.W. Lee, Inverse association between triglyceride glucose index and muscle mass in Korean adults: 2008-2011 knhanes, Lipids Health Dis. 19 (1) (2020) 243.

[20] T.T. Dam, K.W. Peters, M. Fragala, P.M. Cawthon, T.B. Harris, R. McLean, M. Shardell, D.E. Alley, A. Kenny, L. Ferrucci, J. Guralnik, D.P. Kiel, S. Kritchevsky, M. T. Vassileva, S. Studenski, An evidence-based comparison of operational criteria for the presence of sarcopenia, J Gerontol A Biol Sci Med Sci 69 (5) (2014) 584–590.

[21] G.Q. Chen, G.P. Wang, Y. Lian, Relationships Between Depressive Symptoms, Dietary inflammatory potential, and sarcopenia: mediation analyses, Front. Nutr. 9 (2022) 844917.

[22] S. Lin, N. Zhu, S. Zhang, Associations of dietary fiber intake with chronic inflammatory airway diseases and mortality in adults: a population-based study, Front. Public Health 11 (2023) 1167167.

[23] A. Cavaillès, G. Brinchault-Rabin, A. Dixmier, F. Goupil, C. Gut-Gobert, S. Marchand-Adam, J.C. Meurice, H. Morel, C. Person-Tacnet, C. Leroyer, P. Diot, Comorbidities of COPD, Eur. Respir. Rev. 22 (130) (2013) 454–475.

[24] M. Cazzola, P. Rogliani, J. Ora, L. Calzetta, M.G. Matera, Asthma and comorbidities: recent advances, Pol. Arch. Intern. Med. 132 (4) (2022).

[25] J.H. Wee, M.W. Park, C. Min, S.H. Byun, B. Park, H.G. Choi, Association between asthma and cardiovascular disease, Eur. J. Clin. Invest. 51 (3) (2021) e13396.

[26] A.E. Bone, N. Hepgul, S. Kon, M. Maddocks, Sarcopenia and frailty in chronic respiratory disease: lessons from gerontology, Chron. Respir. Dis. 14 (1) (2017) 85–99.

[27] S.H. Kim, M.J. Shin, Y.B. Shin, K.U. Kim, Sarcopenia associated with chronic obstructive pulmonary disease, Journal of bone metabolism 26 (2) (2019) 65–74.

[28] J. Wu, J. Jia, P. Chen, X. Wang, F. Yang, Y. Liu, Y. Ma, J. Jin, Sarcopenia and its clinical correlation in elderly chronic obstructive pulmonary disease: a prospective cohort study, Eur. Rev. Med. Pharmacol. Sci. 27 (20) (2023) 9762–9772.

[29] S.E. Jones, M. Maddocks, S.S. Kon, J.L. Canavan, C.M. Nolan, A.L. Clark, M.I. Polkey, W.D. Man, Sarcopenia in COPD: prevalence, clinical correlates and response to pulmonary rehabilitation, Thorax 70 (3) (2015) 213–218.

[30] Z. Hu, Y. Tian, X. Song, F. Zeng, A. Yang, Associations between sarcopenia with asthmatic prevalence, lung function and comorbidity, BMC Geriatr. 22 (1) (2022) 703.

[31] A. Frizzelli, M. Aiello, L. Calzetta, G. Bertorelli, A. Chetta, The interplay between diabetes mellitus and chronic obstructive pulmonary disease, Minerva Med. 114 (1) (2023) 68–73.

[32] H. Watz, B. Waschki, A. Kirsten, K.C. Müller, G. Kretschmar, T. Meyer, O. Holz, H. Magnussen, The metabolic syndrome in patients with chronic bronchitis and COPD: frequency and associated consequences for systemic inflammation and physical inactivity, Chest 136 (4) (2009) 1039–1046.

[33] C.E. Bolton, M. Evans, A.A. Ionescu, S.M. Edwards, R.H. Morris, G. Dunseath, S.D. Luzio, D.R. Owens, D.J. Shale, Insulin resistance and inflammation - a further systemic complication of COPD, COPD 4 (2) (2007) 121–126.

[34] J. Soo, A. Raman, N.G. Lawler, P.S.R. Goods, L. Deldicque, O. Girard, T.J. Fairchild, The role of exercise and hypoxia on glucose transport and regulation, Eur. J. Appl. Physiol. 123 (6) (2023) 1147–1165.

[35] V. Pellegrinelli, C. Rouault, S. Rodriguez-Cuenca, V. Albert, F. Edom-Vovard, A. Vidal-Puig, K. Clément, G.S. Butler-Browne, D. Lacasa, Human adipocytes induce inflammation and atrophy in muscle cells during obesity, Diabetes 64 (9) (2015) 3121–3134.

[36] L. Feng, Q. Gao, K. Hu, M. Wu, Z. Wang, F. Chen, F. Mei, L. Zhao, B. Ma, Prevalence and risk factors of sarcopenia in patients with diabetes: a meta-analysis, J. Clin. Endocrinol. Metab. 107 (5) (2022) 1470–1483.

[37] H. Zhang, S. Lin, T. Gao, F. Zhong, J. Cai, Y. Sun, A. Ma, Association between sarcopenia and metabolic syndrome in middle-aged and older non-obese adults: a systematic review and meta-analysis, Nutrients 10 (3) (2018).

[38] L. Liu, M. Qin, M. Ji, J. Wang, Correlation between hearing impairment and the Triglyceride Glucose Index: based on a national cross-sectional study, Front. Endocrinol. 14 (2023) 1216718.

[39] T. Chen, Y. Qian, X. Deng, Triglyceride glucose index is a significant predictor of severe disturbance of consciousness and all-cause mortality in critical cerebrovascular disease patients, Cardiovasc. Diabetol. 22 (1) (2023) 156.

[40] A. Khalaji, A.H. Behnoush, S. Khanmohammadi, K. Ghanbari Mardasi, S. Sharifkashani, A. Sahebkar, C. Vinciguerra, A. Cannavo, Triglyceride-glucose index and heart failure: a systematic review and meta-analysis, Cardiovasc. Diabetol. 22 (1) (2023) 244.

[41] S. Liang, C. Wang, J. Zhang, Z. Liu, Y. Bai, Z. Chen, H. Huang, Y. He, Triglyceride-glucose index and coronary artery disease: a systematic review and meta-analysis of risk, severity, and prognosis, Cardiovasc. Diabetol. 22 (1) (2023) 170.

[42] X. Ren, M. Jiang, L. Han, X. Zheng, Association between triglyceride-glucose index and chronic kidney disease: a cohort study and meta-analysis, Nutr Metab Cardiovasc Dis 33 (6) (2023) 1121–1128.

[43] A.H. Behnoush, A. Khalaji, E. Ghondaghsaz, M. Masrour, Z. Shokri Varniab, S. Khalaji, A. Cannavo, Triglyceride-glucose index and obstructive sleep apnea: a systematic review and meta-analysis, Lipids Health Dis. 23 (1) (2024) 4.

[44] A.H. Behnoush, A. Mousavi, E. Ghondaghsaz, S. Shojaei, A. Cannavo, A. Khalaji, The importance of assessing the triglyceride-glucose index (TyG) in patients with depression: a systematic review, Neurosci. Biobehav. Rev. 159 (2024) 105582.

[45] S. Zaigham, H. Tanash, P.M. Nilsson, I.F. Muhammad, Triglyceride-glucose index is a risk marker of incident COPD events in women, Int J Chron Obstruct Pulmon Dis 17 (2022) 1393–1401.