Association of the triglyceride glucose index with computed tomography-based low muscle mass

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Abstract

Introduction: Recent studies have increasingly highlighted the connections between sarcopenia and insulin resistance. The triglyceride glucose (TYG) index has emerged as a promising surrogate marker for insulin resistance; however, its relationship with sarcopenia remains underexplored, and existing findings are inconsistent. This investigation examined this relationship in a Chinese cohort.

Material and methods: The study group comprised individuals aged 50 years or older who underwent computed tomography scans for lung cancer screening. The cross-sectional area of erector spinae was utilized as a marker of muscle mass, with a threshold of 22 cm^2 indicating low muscle mass. Participants were categorized into four subgroups based on quartiles of the TYG index. Logistic regression models were employed to determine the relationship between TYG and low muscle mass.

Results: Among the study cohort, 504 cases of low muscle mass were identified. The prevalence of low muscle mass showed a downward trend as the TYG increased (p = 0.023). The TYG index exhibited a positive correlation with muscle area (β = 0.98, 95% confidence interval (CI): 0.43–1.54). Higher TYG index values were linked to a reduced probability of low muscle area (odds ratio (OR) = 0.74, 95% CI: 0.59–0.95). The OR for low muscle area in the highest quartile compared to the lowest quartile was 0.61 (95% CI: 0.42–0.91). The restricted cubic spline curve corroborated these findings, indicating a consistent trend.

Conclusions: Our findings demonstrated an inverse relationship between the TYG index and the probability of low muscle mass among older adults in the Chinese population.

Key words: low muscle mass; sarcopenia; triglyceride glucose index

Introduction

Sarcopenia, a progressive condition associated with aging, is marked by the deterioration of skeletal muscle mass, strength, and physical function [1]. In recent years, it has become a significant public health issue among older populations. This condition not only severely impacts the quality of life and autonomy of elderly individuals but is also closely linked to a higher risk of various chronic conditions [2, 3], including cardiovascular disease, diabetes, and osteoporosis, as well as increased mortality rates [4]. Therefore, early identification of individuals at risk for sarcopenia is of paramount importance.

Skeletal muscle serves as a primary site for insulin action, and numerous studies have established connections between muscle loss and conditions such as insulin resistance (IR) and diabetes [5, 6]. We speculated that IR may have some roles in identifying sarcopenia. However, assessing IR is complex and not commonly performed in routine clinical settings. The triglyceride glucose (TYG) index is a reliable alternative indicator of IR [7]. The elevated TYG index levels are associated with a higher risk of cardiovascular events [8, 9] and metabolic syndrome [10].

Is there a link between the TYG index and sarcopenia? To date, few studies have explored this connection. Several studies conducted in Korea have indicated that the prevalence of low muscle mass tends to rise with increasing TYG levels or insulin resistance [10–12]. However, young or middle-aged participants were included in those studies. The link between the TYG index and sarcopenia in older adults remains insufficiently examined. Interestingly, Chen *et al.* reported the opposite results in an older Chinese population (> 60 years) [13], and Park *et al.* also observed a negative correlation between muscle mass and diabetes or IR [14]. To better understand these associations, further research is warranted. Therefore, this study aims to explore the relationship between the TYG index and computed tomography-measured muscle mass in an older Chinese population with the goal of early identification and better management of sarcopenia.

Material and methods

Population

This cross-sectional, single-center study received ethical approval from the Institutional Review Board of the Affiliated Hospital of Nanjing University of Chinese Medicine, with a waiver of written informed consent. The study included participants aged 50 years or above who had undergone computed tomography (CT) scans for lung cancer screening at our facility between January 2016 and December 2019. Exclusion criteria comprised a history of malignant tumors, significant renal impairment (estimated glomerular filtration rate below 60 ml/min/1.73 m^2), hepatic dysfunction (indicated by a twofold increase in liver function markers), or rheumatic disorders. Following these exclusions, 1995 eligible participants were included for statistical analyses.

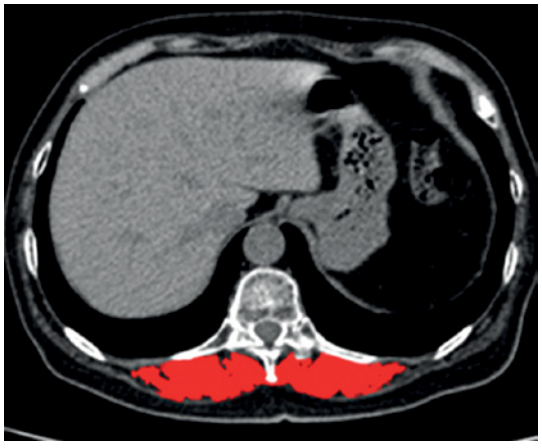

Figure 1. Illustration of the measurement of the muscle area via computed tomography

Data collection

The methodology for data collection has been previously outlined in an earlier publication [15]. In summary, the following variables were documented: demographic characteristics (including age, sex, and body mass index (BMI)), laboratory test outcomes (such as aspartate aminotransferase, serum albumin, high-density lipoprotein cholesterol (HDL-c), low-density lipoprotein cholesterol (LDL-c), total cholesterol (TC), triglyceride (TG) levels, and fasting blood glucose levels), and medical background. Definitions of diabetes mellitus and hepatic dysfunction were established based on serum parameters or clinical history. The TYG index was computed using the formula: Ln(triglyceride (mg/dl) × glucose (mg/dl)/2) [7, 16].

Muscle assessment

Chest CT scans, frequently employed for lung cancer screening, can also assess muscle quality, including muscle area and density [17]. In this study, participants' CT images were used to evaluate the mass of the erector spinae muscles (Figure 1). The detailed information for muscle assessment had been reported in previous studies [15, 17]. The cross-sectional area of these muscles was assessed at the mid-thoracic spine level (T11) using ImageJ software. Reduced muscle mass was defined as an area below the 25th percentile of the study population, corresponding to 22.0 cm^2.

Statistical analysis

The data management and analysis were conducted using SPSS Statistics 20.0 (IBM, USA). Results are reported as means ± standard deviations or as counts (percentages) where appropriate. Statistical tests used included analysis of variance (ANOVA), Student's *t*-test, and the χ^2 test. The TYG index was categorized into four groups based on interquartile (< 8.8, 8.8–9.24, 9.24–9.68, and > 9.68; < 8.12, 0.812–0.863, 0.863–0.905, >0.905 for subjects older than 65 years). To examine the connections between TYG index and muscle mass, linear regression and multivariable logistic regression analyses were conducted. Potential con-

Table I. Characteristics of the subjects divided by TYG index quartile

Parameter	Q1 (*n* = 495)	Q2 (*n* = 505)	Q3 (*n* = 496)	Q4 (*n* = 499)	*P*-value
Age [years]	62.10 ±9.88	62.29 ±9.64	62.26 ±9.36	62.56 ±9.26	0.81
Sex [men]	260 (52.5%)	292 (57.8%)	305 (61.5%)	301 (60.3%)	0.021
Muscle area [cm^2]	26.01 ±6.48	26.37 ±6.58	27.60 ±7.41	27.73 ±7.00	< 0.001
BMI [kg/m^2]	24.52 ±1.92	25.38 ±1.73	26.06 ±1.76	27.06 ±2.21	< 0.001
AST [U/l]	23.61 ±7.49	23.12 ±6.92	23.94 ±6.83	25.49 ±7.56	0.003
Albumin [g/l]	40.16 ±3.15	40.63 ±3.06	40.84 ±2.93	41.43 ±3.21	< 0.001
Creatinine [µmol/l]	75.57 ±29.33	76.64 ±15.50	78.91 ±16.24	79.65 ±29.81	0.022
Blood glucose [mmol/l]	4.99 ±0.62	5.28 ±0.86	5.56 ±1.17	6.38 ±2.06	< 0.001
HDL-c [mmol/l]	1.68 ±0.36	1.55 ±0.33	1.45 ±0.32	1.33 ±0.28	< 0.001
LDL-c [mmol/l]	2.59 ±0.72	2.98 ±0.77	3.08 ±0.81	3.15 ±0.88	< 0.001
TC [mmol/l]	4.43 ±0.94	4.79 ±0.97	4.87 ±1.03	5.06 ±1.06	< 0.001
TG [mmol/l]	0.71 ±0.17	1.12 ±0.19	1.57 ±0.30	2.75 ±1.59	< 0.001
Diabetes	6 (1.2%)	19 (3.8%)	36 (7.3%)	103 (20.6%)	< 0.001
CKD I-II	1 (0.2%)	0 (0)	0 (0)	2 (0.4%)	0.30
TYG index	7.91 ±0.26	8.43 ±0.12	8.81 ±0.11	9.42 ±0.38	< 0.001
Low muscle mass (< 22.0 cm^2)	142	136	123	103	0.023

AST – aspartate aminotransferase, BMI – body mass index, CKD – chronic kidney disease, HDL-c – high-density lipoprotein cholesterol, HU – Hounsfield unit, LDL-c – low-density lipoprotein cholesterol, TC – total cholesterol, TG – triglyceride, TYG – triglyceride glucose.

founders included in the analysis were age, sex, BMI, liver function, renal function, diabetes status, albumin levels, LDL-c, and HDL-c. Additionally, a weighted restricted cubic spline (RCS) analysis was used to further explore the association between the TYG index and low muscle mass. A significance threshold of $\alpha = 0.05$ was applied for all statistical tests.

Results

Participant characteristics

Table I provides an overview of the characteristics of the 1995 participants stratified by quartiles of the TYG index. As the TYG index quartile increased, muscle area, BMI, serum albumin, creatinine, blood glucose, LDL-c, TC, and TG levels, as well as the prevalence of diabetes, showed an upward trend. Conversely, HDL-c levels decreased across quartiles. The proportion of male participants was lowest in the first quartile (Q1) and highest in the third quartile (Q3).

Associations between the TYG index and muscle area

The relationship between the TYG index and muscle area was examined using linear regression analysis (Table II). After accounting for potential confounders, TYG index was positively correlated with muscle area ($\beta = 0.98$, 95% confidence interval (CI): 0.43–1.54, $p < 0.01$). Age and sex were also correlated with muscle area ($\beta = -0.20$, 95% CI: –0.23 to –0.17; $\beta = 5.71$, 95% CI: 5.09–6.34).

Associations between the TYG index and low muscle mass

We further explored the relationship between the TYG index and low muscle area using logistic regression analysis (Table III). The results showed that the TYG index was a significant predictor of low muscle mass across various models. Specifically, in the age-, sex-, and BMI-adjusted models, as well as the fully adjusted model, a higher TYG index was associated with a lower likelihood of low muscle mass (odds ratio [OR] = 0.76, 95% CI: 0.61–0.94, $p < 0.001$; OR = 0.74, 95% CI: 0.59–0.95, $p = 0.02$).

Table III also details the prevalence of low muscle mass across different TYG quartiles. When compared to the Q1 of the TYG index, participants in the highest quartile (Q4) exhibited a reduced prevalence of low muscle mass (OR = 0.63, 95% CI: 0.44–0.89), after adjustment for age, sex, and BMI. This association remained consistent even

Table II. Linear regression analysis between the TYG index and muscle area

Parameter	β (95% CI)	*P*-value
TYG (continuous)	0.98 (0.43–1.54)	0.001
Age [years]	–0.20 (–0.23 to –0.17)	< 0.001
Gender	5.71 (5.09–6.34)	< 0.001
BMI [kg/m^2]	–0.21 (–0.43–0.06)	0.06

The model was adjusted for liver function, renal function, diabetes, albumin, low-density lipoprotein cholesterol and high-density lipoprotein cholesterol. BMI – body mass index, CI – confidence interval, TYG – triglyceride glucose.

Table III. Association between the TYG index and the risk of low muscle mass

Parameter	Model 1	*P*-value	Model 2	*P*-value	Model 3	*P*-value
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
TYG (continuous)	0.76 (0.61–0.94)	< 0.001	0.72 (0.57–0.92)	0.007	0.74 (0.59–0.95)	0.02
Q1 (< 8.80)	1		1		1	
Q2 (8.80–9.24)	0.96 (0.71–1.31)	0.96	0.94 (0.69–1.28)	0.69	0.95 (0.69–1.30)	0.75
Q3 (9.24–9.68)	0.88 (0.63–1.21)	0.88	0.84 (0.61–1.17)	0.31	0.86 (0.62–1.21)	0.39
Q4 (> 9.68)	0.63 (0.44–0.89)	0.01	0.59 (0.40–0.86)	0.006	0.61 (0.42–0.91)	0.01

Model 1 was adjusted for age, sex and body mass index. Model 2 was further adjusted for liver function, renal function, diabetes status, and the ALB concentration. Model 3 was further adjusted for low-density lipoprotein cholesterol and high-density lipoprotein cholesterol. CI – confidence interval, OR – odds ratio, TYG – triglyceride glucose.

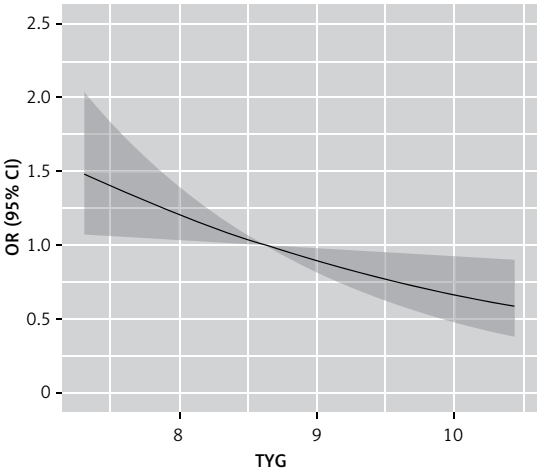

Figure 2. Restricted cubic splines showing the multivariable adjusted odds ratio for the risk of low muscle mass according to the triglyceride glucose (TYG) index. Age, sex and body mass index, liver function, renal function, diabetes, low-density lipoprotein cholesterol, albumin and high-density lipoprotein cholesterol were adjusted

after additional adjustments for liver function, renal function, diabetes, albumin, low-density lipoprotein cholesterol, and HDL-c (OR = 0.61, 95% CI: 0.42–0.91). Furthermore, a weighted restricted cubic spline (RCS) analysis (Figure 2) demonstrated a nonlinear negative correlation between the TYG index and the prevalence of low muscle mass, suggesting that higher TYG index values were associated with a decreased risk of low muscle mass.

Subgroup analyses were performed in subjects older than 65 years. Individuals with the Q4 of TYG consistently exhibited a reduced probability of having low muscle mass across all three models (OR = 0.56, 95% CI: 0.31–0.99; OR = 0.53, 95% CI: 0.28–0.99; OR = 0.52, 95% CI: 0.27–0.99) (Table IV).

Discussion

Previous research has established a relationship between IR and sarcopenia [5, 18]. Given this connection, we hypothesized that the TYG index might be associated with low muscle mass. However, studies exploring this relationship, particularly among older adults, are limited, and existing findings are inconsistent. This study investigated the association between the TYG index and low muscle mass among 1995 Chinese participants aged 50 years and above. Our results demonstrated a negative correlation between the TYG index and muscle area, as well as the prevalence of low muscle mass. This association persisted even after accounting for potential confounding factors, including sex, age, BMI, and liver and kidney function.

The relationship between the TYG index and low muscle mass has been explored in only a handful of studies [11–14], with results that are not yet consistent. For instance, Chen *et al.* [19] found that a higher TYG index was related to sarcopenia

Table IV. Association between the TYG index and the risk of low muscle mass in participants older than 65 years

Parameter	Model 1	*P*-value	Model 2	*P*-value	Model 3	*P*-value
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
TYG (continuous)	0.77 (0.56–1.06)	0.11	0.64 (0.44–0.94)	0.02	0.70 (0.48–1.00)	0.049
Q1	1		1		1	
Q2	0.76 (0.45–1.26)	0.29	0.81 (0.48–1.35)	0.42	0.80 (0.47–1.34)	0.40
Q3	0.96 (0.57–1.62)	0.87	0.88 (0.51–1.50)	0.63	0.89 (0.52–1.53)	0.67
Q4	0.56 (0.31–0.99)	0.047	0.53 (0.28–0.99)	0.048	0.52 (0.27–0.99)	0.047

Model 1 was adjusted for age, sex and body mass index. Model 2 was further adjusted for liver function, renal function, diabetes status, and the ALB concentration. Model 3 was further adjusted for low-density lipoprotein cholesterol and high-density lipoprotein cholesterol. CI – confidence interval, OR – odds ratio, TYG – triglyceride glucose. Q1: < 8.12, Q2: 0.812–0.863, Q3: 0.863–0.905, Q4 > 0.905.

in nondiabetic patients undergoing maintenance hemodialysis. In contrast, a U.S. population study reported high TYG index values in individuals with sarcopenia compared to those without sarcopenia [20]. Similarly, multiple population-based studies from Korea have reported a significant correlation those two factors [11, 12, 21]. However, a recent longitudinal study from China showed an inverse relationship: the TYG index was negatively related to the incidence of sarcopenia, although this association became nonsignificant after adjusting for BMI [13]. Interestingly, a recent cross-sectional study also showed that high TYG index was a protective factor against sarcopenia in middle aged and older women (n = 460) [22]. The prevalence of sarcopenia in the high TYG group was significantly greater than that in the low TYG group (20% vs. 8.7%) [22]. Additionally, a Korean study reported a negative correlation between skeletal muscle index and the risk of diabetes or IR [14]. Those studies and our data suggested that elevated TYG levels may be beneficial in reducing the risk of fractures in elderly individuals.

Our study found that the prevalence of reduced muscle mass decreased with increasing TYG value, aligning with the findings of the recent Chinese and Korean studies [13, 14]. These discrepancies across studies may arise from differences in study design, population characteristics, race, or methods used to measure muscle mass. Furthermore, our study focused primarily on older adults, whereas other studies have often included younger populations. It is important to note that older individuals are particularly susceptible to sarcopenia, and the relationship between the TYG index and muscle mass may vary in younger populations or those with different health conditions. Further research is needed to clarify these associations.

The underlying mechanisms linking the TYG index to low muscle mass remain unclear. Insulin is a hormone that facilitates glucose uptake in muscle cells, promoting energy utilization and storage [23]. Skeletal muscle is one of the critical target organs for insulin actions [23]. Elevated IR can impair glucose uptake in skeletal muscle, while reduced muscle mass can also exacerbate insulin resistance. This interplay suggests that IR may influence muscle metabolism and mass. However, our results suggest that higher levels of TYG, which reflect greater insulin resistance, might paradoxically correlate with preserved muscle mass. Chen *et al*. [13] highlighted that BMI could be a significant factor in the relationship between IR and sarcopenia. In our study, participants with a higher TYG index also had higher BMI values. This suggests that BMI might mediate the observed negative association between the TYG index and low muscle mass. Additionally, recent research has shown that older adults with high HDL-c levels (> 70 mg/dl) are at increased risk of sarcopenia [24]. Our data revealed that participants with the lowest TYG index had notably elevated HDL-c levels compared to those with the highest TYG index. This difference in HDL-c levels could also contribute to the observed negative association. Furthermore, chronic inflammation is a common feature in individuals with sarcopenia [25, 26] and is also linked to insulin resistance [27]. This inflammatory state may influence both muscle mass and insulin sensitivity, potentially complicating the relationships between TYG index and muscle health.

Our study has several limitations that should be acknowledged. Firstly, while we accounted for multiple potential confounders, we did not consider other important factors such as physical activity levels (e.g., daily walking distance, exercise frequency) or lifestyle habits such as smoking and alcohol consumption. These factors could significantly influence both muscle mass and insulin resistance. Secondly, we were unable to fully elucidate the mechanisms underlying the relationship between the TYG index and sarcopenia. For example, oxidative stress and inflammation are potential pathways linking the TYG index to reduced muscle mass [28, 29]. However, we did not measure oxidative stress markers (e.g., SOD, MDA) or systemic inflammation indicators in our study population. Thirdly, our study employed a cross-sectional design. Longitudinal studies would be more effective in clarifying the causal associations over time. Fourthly, our analysis focused solely on muscle mass. We did not examine the potential associations between muscle strength, physical performance, and the TYG index, which could provide additional insights into sarcopenia. Lastly, our study was conducted at a single center, which may limit the generalizability of our findings. Future research should involve multicenter studies with larger and more diverse sample sizes to validate our results and further explore these relationships.

In conclusion, in our investigation, a higher TYG index correlated with lower probability of low muscle mass among older Chinese adults. This association highlights the intricate nature of sarcopenia and emphasizes the need for additional research to elucidate the mechanisms at play. From a clinical perspective, the TYG index could serve as a useful indicator for identifying individuals at risk of sarcopenia, thereby facilitating interventions to improve muscle health and overall well-being in the elderly. Future studies should prioritize longitudinal designs to better understand the causal dynamics and the role of the TYG index in the development and progression of sarcopenia.

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Ethical approval

Ethics approval was obtained from our institution. The study was performed in accordance with the Declaration of Helsinki. The need for informed consent was waived by the Ethics Committee of our institution because of the retrospective nature of the study.

Conflict of interest

The authors declare no conflict of interest.

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