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ORIGINAL RESEARCH

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Risk factor analysis and prediction model development for the occurrence of sarcopenia in middle-aged and elderly men with newly diagnosed type 2 diabetes mellitus

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Abstract

To develop a prediction model to forecast the onset of sarcopenia in middle-aged and elderly men with type 2 diabetes mellitus (T2DM), this study examined the risk factors contributing to sarcopenia in these individuals. Clinical data of 525 middle-aged and elderly men newly diagnosed with T2DM were retrospectively analyzed. After rigorous data filtering and preprocessing, eligible patients (n = 525) were randomized into the training cohort (n = 394) and validation cohort (n = 131) in a ratio of 3:1. Using sarcopenia in the training cohort as the outcome variable, multivariate logistic regression analysis was performed to identify independentpredictors. The nomogram prediction model was further constructed on theses basis. The constructed prediction model was externally validated using the validation cohort. The 525 newly diagnosed middle-aged and elderly men with T2DM included 451 patients without sarcopenia and 74 patients with sarcopenia, and the incidence of sarcopenia was 14.10%. In the training cohort, the occurrence of sarcopenia in male patients with T2DM was independently associated with age (60–74 years), age ($\geq$75 years), body mass index (BMI) $<$24 kg/cm^2, albumin $<$40 g/L, glycosylated hemoglobin A1c (HbA1c) ($>$7%), Albuminuria, non-alcoholic fatty liver disease (NAFLD) and Insulin use ($p < 0.05$). After adjusting for age and BMI, albumin $<$40 g/L, HbA1c ($>$7%), Albuminuria, and NAFLD remained independent predictors of sarcopenia in men with T2DM ($p < 0.05$). The screened variables were included in the nomogram prediction model. The area under the curve of the training cohort and validation cohort prediction models were 0.912 and 0.897, respectively. The Hosmer-Lemeshow test showed a good fit in the training and validation cohorts ($p > 0.05$). In middle-aged and older men with T2DM, we successfully developed, and validated a high-precision nomogram model that may improve early identification and screening of individuals at high risk for sarcopenia.

Keywords

Newly diagnosed type 2 diabetes; Male; Sarcopenia; Age

1. Introduction

Sarcopenia is a geriatric condition characterized by a decrease in muscle mass accompanied with a reduced or impaired mobility as one ages [1]. Sarcopenia has a significant correlation with a higher risk of various adverse outcomes, including falls, fractures, physical dysfunction, disability, and an increased frequency of hospitalizations, as well as a lower quality of life and, eventually mortality. In recent years, it has been found that elderly patients with type 2 diabetes mellitus (T2DM) are two to three times more likely to develop sarcopenia than the general population [2]. Additionally, sarcopenia can exacerbate the abnormal glucose metabolism in T2DM patients, leading to the progression of diabetes mellitus and further increasing albuminuria [3]. Furthermore, sarcopenia, which is strongly linked to falls in individuals with type 2 diabetes, often manifests as a decreased gait speed [4]. Falls are known to significantly increase the hospitalization rates in these patients, resulting in bed rest, which heightens the risk of lung infections and further lowers the quality of life for elderly diabetic patients. Moreover, recent evidence suggests that newly diagnosed T2DM increases the 10-year risk of cerebrovascular disease in men [5]. However, it remains unknown whether newly diagnosed T2DM equally affects the risk of sarcopenia in men. Therefore, improving the screening, diagnosis and intervention for sarcopenia in the diabetic population is critical.

Sarcopenia can be accelerated by a variety of factors, including hormonal changes, chronic diseases, and malnutrition [6]. Among these, sex hormones play an important role in

maintaining bone homeostasis. A significant correlation between age-related decline in testosterone and frailty in older men has been reported [7]. In addition, male hypogonadism is diagnosed when serum total and free testosterone concentrations are consistently low [8]. In contrast, approximately 25–33% of men with T2DM suffer from hypogonadotropic hypogonadism, which is considered a risk factor for the development of T2DM [9]. However, studies based on different study populations (such as different sexes and different age groups) showed large differences in the prevalence of sarcopenia, ranging between 7.2% and 31.1% [10, 11]. Furthermore, there are fewer studies on the occurrence of sarcopenia in male T2DM patients. Given this, the present study was conducted to analyze the risk factors associated with sarcopenia development in newly diagnosed middle-aged and elderly men with T2DM. Moreover, this study is based on a nomogram model constructed using economical, efficient and easily accessible parameters, with the goal of providing a basis for the clinical prevention of sarcopenia.

2. Materials and methods

2.1 Patients

Clinical data of 525 newly diagnosed T2DM middle-aged and elderly men hospitalized in The People's Hospital of Shijiazhuang were retrospectively analyzed. The diagnosis of T2DM was by the 1999 World Health Organization diagnostic criteria [12], *i.e.*, fasting blood glucose (FBG) $\geq$7.0 mmol/L and/or 2-h blood glucose $\geq$11.1 mmol/L on oral glucose tolerance test. Inclusion criteria: (1) patients with a definite diagnosis of T2DM; (2) age $\geq$45 years, male; (3) duration of diabetes $<$1 year. Exclusion criteria: (1) patients with severe cardiovascular disease (heart failure class III or IV); (2) patients with combined autoimmune hepatitis, cirrhosis, or hepatocellular carcinoma, or in the presence of severe hepatic impairment; (3) patients with severe renal impairment (estimated glomerular filtration rate (eGFR) $<30\ \mathrm{mL \cdot min^{-1} \cdot (1.73\ m^2)^{-1}}$); (4) patients diagnosed with malignant tumors; (5) patients in the acute infectious phase; (6) patients using medications affecting sodium retention, such as diuretics and hormones; and (7) patients with a variety of disorders that cause sodium retention.

2.2 Sample size calculation

This was a retrospective study of newly diagnosed T2DM in middle-aged and elderly men. Generally, an area under the receiver operating characteristic (ROC) curve (AUC) $<$0.7 suggests low model accuracy, while when the AUC $>$0.8 indicates high diagnostic efficacy. Setting the test level α = 0.05, power $1 - \beta = 0.9$, $N^-/N^+ = 2$, the total sample size was calculated to be at least 506.

2.3 Diagnosis of sarcopenia

According to the 2014 Asian Sarcopenia Working Group Consensus [13], muscle mass was measured using the appendicular skeletal muscle mass index (ASMI). The diagnostic criterion for decreased muscle mass was defined as being below the lowest quintile of healthy young individuals of the same race and gender. Reduced muscular strength was defined as grip strength below the lowest quartile of patients of the same sex. Sarcopenia was diagnosed when both decreased muscle mass and decreased strength were present. The Bioelectrical Impedance Analysis method was used for testing and the lowest quintile of ASMI was calculated to be 7.18 $\mathrm{kg/m^2}$ for males and 5.73 $\mathrm{kg/m^2}$ for females, respectively.

The lowest quintile cut-off value for grip strength was 29.5 kg for males and 21.2 kg for females, below which muscle strength was defined as decreased. A certified technician used a Dual-energy X-ray Absorptiometry (DXA) Hologic scanner (Medix90, MEDILINK SARL, Mauguio, France) to measure the patient's bodycomposition. Using the Hologic whole-body DXA reference database software (Medix90, MEDILINK SARL, Mauguio, France), local and whole-body muscle tissue was evaluated. The appendicular skeletal muscle mass (ASM) of the extremities was calculated as the total muscle mass of the bilateral upper and bilateral lower extremities. $\mathrm{ASM/height^2}$ = ASMI ($\mathrm{kg/m^2}$). Grip strength was measured using an EH101 electronic grip strength meter (Yiwu Yingjie Electronic Technology Co., Yiwu, ZheJiang, China), and the left and right hands were sequentially measured twice each, and the maximum value was recoded.

2.4 Basic information collection

Based on the e-portfolio record, general clinical information of the patients was collected, including age, duration of diabetes, body mass index (BMI), history of smoking, history of alcohol consumption, comorbidities (*e.g.*, hypertension, coronary artery disease, sarcopenia, albuminuria, non-alcoholic fatty liver disease (NAFLD)), type of hypoglycemic therapy medication, body component examination, abdominal ultrasonography, and laboratory indices (*e.g.*, FBG, glycosylated hemoglobin A1c (HbA1c), white blood cell count (WBC), neutrophil percentage, serum albumin (ALB), hemoglobin, total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), uric acid (UA), serum creatinine (SCr), aspartate aminotransferase (AST), alanine aminotransferase (ALT), ultrasensitive C-reactive protein (hsCRP)).

2.5 Statistical analysis

All statistical analyses were performed using the SPSS software version 23.0 (IBM Corp., SPSS Statistics, Armonk, NY, USA) and R 4.3.2 software. A significance level of $p < 0.05$ was considered statistically significant. Data were expressed as mean $\pm$ standard deviation (SD) or median (interquartile range), as appropriate. Continuous variables were compared using Student's *t*-test or Mann-Whitney U test, as appropriate, and categorical variables were compared using the χ^2 test or Fisher's exact test, as appropriate. Univariate and multivariate logistic regression analyses were used to screen the characteristic indicators. Through rigorous data filtering and preprocessing, eligible patients (n = 525) were randomly divided into the training cohort (n = 394) and validation cohort (n = 131) in a ratio of 3:1. Multivariate logistic regression analysis was used to screen out independent influences using sarcopenia in the training cohort data as an outcome variable.

The nomogram prediction model was further established on this basis. The constructed prediction model was validated using validation cohort data. The ROC curve was used to verify the prediction performance of the model. The goodness of fit of the model was assessed using the Hosmer-Lemeshow goodness-of-fit test, and calibration curves were plotted. Also, decision curve analysis (DCA) was used to predict the risk of sarcopenia occurrence.

3. Results

3.1 General information

The 525 newly diagnosed middle-aged and elderly men with T2DM included 451 without sarcopenia (non-sarcopenia group) and 74 with sarcopenia (sarcopenia group), with a Sarcopenia incidence of 14.10%. Among 525 middle-aged and older men with T2DM, 394 belonged to the training cohort and 131 to the validation cohort. The difference between the training cohort and validation cohort was not statistically significant in all baseline indices ($p > 0.05$, Tables 1,2).

3.2 Comparison of clinical data of sarcopenia and non-sarcopenia patients in the training cohort

In the training cohort, the differences in the proportional distribution of age, BMI, ALB, FBG, HbA1c, Albuminuria, NAFLD, and Sulfonylureas, Metformin, and Insulin use in the sarcopenia and non-sarcopenia groups were statistically significant ($p < 0.05$, Table 3). Compared with the non-sarcopenia group, the proportions of T2DM men in the sarcopenia group with age 60–74 years, age ≥75 years, BMI <24 kg/cm^2, ALB <40 g/L, FBG >8.5 mmol/L, HbA1c >7%, Albuminuria, NAFLD, and Sulfonylureas use were significantly higher, while the proportions of those using metformin and insulin were significantly lower ($p < 0.05$, Tables 3,4). The sarcopenia group had significantly higher proportions of patients with age 60–74 years, age ≥75 years, BMI <24 kg/cm^2, ALB <40 g/L, FBG >8.5 mmol/L, HbA1c >7%, Albuminuria, NAFLD, and Sulfonylureas use, and significantly lower proportions of metformin and insulin use compared to the non-sarcopenia group ($p < 0.05$, Tables 3,4).

3.3 Multivariate logistic regression analysis

Multivariate logistic regression analysis was conducted with sarcopenia as the dependent variable. According to Model 1, the occurrence of sarcopenia in male patients with T2DM was independently associated with age (60–74 years), age (≥75 years), BMI <24 kg/cm^2, ALB <40 g/L, HbA1c (>7%), albuminuria, NAFLD, and insulin use ($p < 0.05$, Table 5). After correcting for age and BMI (Model 2), ALB <40 g/L, HbA1c (>7%), albuminuria, and NAFLD remained independent predictors of sarcopenia development in men with T2DM ($p < 0.05$, Table 5).

TABLE 1. Comparison of general information between training and validation cohort for T2DM men.

Parameters	Training cohort (n = 394)	Validation cohort (n = 131)	Statistical value	*p*
Age (n, %)				
45–59 yr	197 (50.00%)	56 (42.75%)		
60–74 yr	124 (31.47%)	39 (29.77%)	4.960	0.084
≥75 yr	73 (18.53%)	36 (27.48%)		
BMI (n, %)				
≥24 kg/m^2	271 (68.78%)	91 (69.47%)	0.021	0.883
<24 kg/m^2	123 (31.22%)	40 (30.53%)		
Smoking (n, %)	308 (78.17%)	104 (79.39%)	0.086	0.769
Alcohol (n, %)	234 (59.39%)	81 (61.83%)	0.244	0.621
History of hypertension (n, %)	305 (77.41%)	105 (80.15%)	0.432	0.511
History of coronary heart disease (n, %)	91 (23.10%)	28 (21.37%)	0.166	0.683
Albuminuria (n, %)	112 (28.43%)	34 (25.95%)	0.299	0.584
NAFLD (n, %)	101 (25.63%)	37 (28.24%)	0.346	0.557
Medication				
Metformin (n, %)	249 (63.20%)	84 (64.12%)	0.036	0.849
Sulfonylureas (n, %)	105 (26.65%)	41 (31.30%)	1.058	0.304
a_glucosidase.inhibitors (n, %)	101 (25.63%)	41 (31.30%)	1.598	0.206
Insulin (n, %)	255 (64.72%)	93 (70.99%)	1.730	0.188
Sarcopenia (n, %)	54 (13.71%)	20 (15.27%)	0.198	0.656

BMI: body mass index; NAFLD: non-alcoholic fatty liver disease.

TABLE 2. Comparison of clinical data between training and validation cohort for T2DM men.

Parameters	Training cohort (n = 394)	Validation cohort (n = 131)	Statistical value	*p*
WBC ($\times 10^9$/L, mean ± SD)	5.87 ± 1.88	5.92 ± 1.71	0.243	0.808
Neutrophil percentage (%)	61.39 ± 12.67	62.79 ± 13.14	1.080	0.281
SCr (μmol/L, mean ± SD)	80.20 ± 19.97	80.83 ± 18.67	0.319	0.750
eGFR (mL·min^{-1}·(1.73 m^2)$^{-1}$, mean ± SD)	207.61 ± 82.12	198.88 ± 79.18	1.064	0.288
serum UA (μmol/L, mean ± SD)	297.70 ± 99.01	294.64 ± 99.30	0.306	0.760
Hemoglobin (g/L, mean ± SD)	127.81 ± 28.40	127.86 ± 29.71	0.017	0.986
ALB (n, %)				
≥40 g/L	290 (73.60%)	88 (67.18%)	2.015	0.156
<40 g/L	104 (26.40%)	43 (32.82%)		
ALT (U/L, mean ± SD)	22.22 ± 7.65	21.98 ± 7.92	0.317	0.751
AST (U/L, mean ± SD)	21.55 ± 8.03	22.33 ± 7.23	0.997	0.319
TC (mmol/L, mean ± SD)	4.11 ± 1.56	4.17 ± 1.43	0.367	0.714
TG (mmol/L, mean ± SD)	4.06 ± 1.48	4.03 ± 1.27	0.254	0.800
HDL-C (mmol/L, mean ± SD)	1.04 ± 0.48	0.99 ± 0.42	0.984	0.325
LDL-C (mmol/L, mean ± SD)	2.29 ± 0.92	2.28 ± 0.81	0.133	0.894
FBG (n, %)				
≤8.5 mmol/L	227 (57.61%)	80 (61.07%)	0.483	0.487
>8.5 mmol/L	167 (42.39%)	51 (38.93%)		
HbA1c (n, %)				
≤7%	207 (52.54%)	78 (59.54%)	1.943	0.163
>7%	187 (47.46%)	53 (40.46%)		
hsCRP (mg/L, mean ± SD)	1.59 ± 0.49	1.59 ± 0.50	0.134	0.893

WBC: white blood cell count; SCr: serum creatinine; eGFR: estimated glomerular filtration rate; UA: uric acid; ALB: serum albumin; ALT: alanine aminotransferase; AST: aspartate aminotransferase; TC: total cholesterol; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; FBG: fasting blood glucose; HbA1c: glycosylated hemoglobin A1c; hsCRP: ultrasensitive C-reactive protein; SD: standard deviation.

3.4 Construction of the nomogram model

Variables screened as a result of the Model 1 analysis were included in the nomogram prediction model, and the outcome indicator was the risk of developing sarcopenia, which was plotted in a nomogram (Fig. 1). Based on the scale above the nomogram corresponding to each risk factor, a single score for that factor is obtained. The sum of all risk factor scores gives a total score which corresponds to the incidence of sarcopenia in the corresponding patient. A higher total score indicates a greater likelihood of sarcopenia risk.

3.5 Validation and evaluation of the nomogram model

Further, ROC curves of nomogram prediction accuracy were plotted in the training cohort and validation cohort (Fig. 2). The area under the ROC curve for the training cohort was 0.912 (95% CI: 0.865–0.959), with a sensitivity of 79.98% and specificity of 91.33%, and for the validation cohort, the area under the ROC curve was 0.897 (95% CI: 0.801–0.993), with a sensitivity of 84.32% and specificity of 91.07%. These data suggested that the prediction model demonstrates good discriminative ability in both the training and validation cohorts. Additionally, in the training cohort, the correction curve of the nomogram showed that the predictions were in good agreement with observations (Fig. 3A). The Hosmer-Lemeshow test showed that the model was not significant (p = 0.427), indicating that the model fit the observed data well. External validation by the validation cohort observed similar results (Fig. 3B) and the Hosmer-Lemeshow test indicated that the model was not significant (p = 0.322). On the basis of the nomogram prediction model, the screened variables were subjected to DCA for sarcopenia in the training cohort (Fig. 4A). The results showed that the net benefit of this nomogram for predicting the risk of sarcopenia in T2DM men was higher when the threshold probability of the patient was 0 to 0.9, which was also confirmed in the validation cohort (Fig. 4B).

4. Discussion

This study investigated the relationship between T2DM and sarcopenia in a population of middle-aged and elderly men. In this study, we found that age, BMI, ALB, HbA1c, albuminuria,

TABLE 3. Comparison of general information of sarcopenia and non-sarcopenia patients in the training cohort.

Parameters	non-Sarcopenia (n = 340)	Sarcopenia (n = 54)	Statistical value	*p*
Age (n, %)			16.944	<0.001
45–59 yr	184 (54.12%)	13 (24.07%)	16.824	<0.001
60–74 yr	99 (29.12%)	25 (46.30%)	6.376	0.012
≥75 yr	57 (16.76%)	16 (29.63%)	5.109	0.024
BMI (n, %)				
≥24 kg/cm^2	248 (72.94%)	23 (42.59%)	19.988	<0.001
<24 kg/cm^2	92 (27.06%)	31 (57.41%)		
Smoking (n, %)	263(77.35%)	45 (83.33%)	0.977	0.323
Alcohol (n, %)	202 (59.41%)	34 (62.96%)	0.245	0.621
History of hypertension (n, %)	262 (77.06%)	43 (79.63%)	0.176	0.675
History of coronary heart disease (n, %)	78 (22.94%)	13 (24.07%)	0.034	0.854
Albuminuria (n, %)	78 (22.94%)	34 (62.96%)	36.686	<0.001
NAFLD (n, %)	73 (21.47%)	28 (51.85%)	22.563	<0.001
Medication History				
Metformin (n, %)	223 (65.59%)	26 (48.15%)	6.094	0.014
Sulfonylureas (n, %)	84 (24.71%)	21 (38.89%)	4.795	0.029
a_glucosidase.inhibitors (n, %)	87 (25.58%)	14 (25.93%)	0.003	0.958
Insulin (n, %)	240 (70.59%)	15 (27.78%)	37.404	<0.001

BMI: body mass index; NAFLD: non-alcoholic fatty liver disease.

NAFLD and insulin use were all independent influences on the occurrence of sarcopenia in newly diagnosed middle-aged and elderly men with T2DM. Additionally, this study developed an accurate personalized sarcopenia risk prediction model based on the above independent influences using sarcopenia as an outcome variable. This model aims to provide a reference for clinicians in the early screening of sarcopenia in middle-aged and elderly T2DM patients.

In this study, the prevalence of sarcopenia in the male T2DM population was 14.10%, and it showed a significant increasing trend with age, consistent with previous studies. Logistic regression analysis also showed that increasing age was an independent correlate of sarcopenia. Comorbid debility or sarcopenia in elderly diabetic patients is not uncommon in clinical practice. Studies have shown that combined debility or sarcopenia in diabetic patients aged 50 to 90 years accounted for 28.8% and 29.3%, respectively [14]. The prevalence of sarcopenia was significantly higher in diabetic patients over 60 years of age than in the healthy population [15]. This study discovered that BMI, ALB, HbA1c, FBG and insulin use were all linked to the onset of sarcopenia in males with T2DM. According to Kim *et al*. [16], 57.6% of T2DM patients with a BMI <24 km/cm^2 had reduced muscle mass detected. This finding aligns with the Fukuoka research [17], which suggested that a high-fat percentage and low BMI may increase the risk of sarcopenia. Our study independently correlated with sarcopenia in male T2DM patients with low BMI. One of the risk factors known for sarcopenia development is inadequate nutrition [18]. Maintaining muscular bulk and function requires an adequate energy intake, while inadequate energy intake causes rapid muscle atrophy and decreased mitochondrial energy metabolism in muscle fibers. In older adult, decreased muscle mass, muscular strength, and gait speed are linked to low blood ALB levels. It has been demonstrated that sarcopenia and serum ALB <40 g/L in older persons increase the risk of abrupt impairment [19]. ALB <40 g/L was also linked to a higher incidence of sarcopenia in middle-aged and older T2DM patients, according to the current investigation. Previous research has demonstrated a linear relationship between HbA1c and sarcopenia, particularly in non-obese people [20]. The current study also discovered that among middle-aged and older males with type 2 diabetes, having a HbA1c >7% was an independent risk factor for the development of sarcopenia. Long-term variations in blood sugar levels can worsen problems related to the micro and macrovascular systems and raise the risk of death from all causes [21]. Besides hyperglycemia itself, reduced insulin function may contribute to the link between hyperglycemia and sarcopenia as insulin is a well-known anabolic hormone that stimulates the synthesis of muscle proteins. Thus, in middle-aged and older men, maintaining a healthy BMI within an acceptable range, eating well, and actively managing blood glucose levels may help delay the onset of sarcopenia.

Chinese individuals with type 2 diabetes frequently experience chronic renal disease [22]. In older T2DM patients, albuminuria is a hallmark change of renal illness and is directly linked to the beginning and development of muscle loss [23]. In this study, we discovered that individuals with T2DM exacerbated by albuminuria had a considerably greater frequency of sarcopenia. In middle-aged and older men with type 2 dia-

TABLE 4. Comparison of clinical data of sarcopenia and non-sarcopenia patients in the training cohort.

Parameters	non-Sarcopenia (n = 340)	Sarcopenia (n = 54)	Statistical value	*p*
WBC ($\times 10^9$/L, mean ± SD)	5.91 ± 1.90	5.66 ± 1.71	0.896	0.371
Neutrophil percentage (%)	61.28 ± 12.48	62.09 ± 13.90	0.433	0.665
SCr (μmol/L, mean ± SD)	80.14 ± 20.12	80.57 ± 19.23	0.144	0.885
eGFR (mL·min^{-1}·(1.73 m^2)$^{-1}$, mean ± SD)	205.61 ± 80.58	220.23 ± 91.03	1.216	0.225
serum UA (μmol/L, mean ± SD)	297.88 ± 100.37	296.00 ± 90.81	0.095	0.924
Hemoglobin (g/L, mean ± SD)	127.89 ± 28.94	127.29 ± 24.96	0.145	0.884
ALB (n, %)				
≥40 g/L	267 (78.53%)	23 (42.59%)	30.975	<0.001
<40 g/L	73 (21.47%)	31 (57.41%)		
ALT (U/L, mean ± SD)	22.31 ± 7.73	21.69 ± 7.21	0.554	0.580
AST (U/L, mean ± SD)	21.51 ± 8.22	21.77 ± 6.79	0.216	0.829
TC (mmol/L, mean ± SD)	4.10 ± 1.54	4.21 ± 1.64	0.487	0.626
TG (mmol/L, mean ± SD)	4.08 ± 1.48	3.97 ± 1.52	0.476	0.635
HDL-C (mmol/L, mean ± SD)	1.03 ± 0.48	1.11 ± 0.48	1.168	0.243
LDL-C (mmol/L, mean ± SD)	2.30 ± 0.92	2.21 ± 0.93	0.733	0.464
FBG (n, %)				
≤8.5 mmol/L	208 (61.18%)	19 (35.19%)	12.891	<0.001
>8.5 mmol/L	132 (38.82%)	35 (64.81%)		
HbA1c (n, %)				
≤7%	196 (57.65%)	11 (20.37%)	25.968	<0.001
>7%	144 (42.35%)	43 (79.63%)		
hsCRP (mg/L, mean ± SD)	1.60 ± 0.49	1.56 ± 0.51	0.469	0.640

WBC: white blood cell count; SCr: serum creatinine; eGFR: estimated glomerular filtration rate; UA: uric acid; ALB: serum albumin; ALT: alanine aminotransferase; AST: aspartate aminotransferase; TC: total cholesterol; TG: triglycerides; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; FBG: fasting blood glucose; HbA1c: glycosylated hemoglobin A1c; hsCRP: ultrasensitive C-reactive protein; SD: standard deviation.

TABLE 5. Multivariate logistic regression analysis.

	Model 1			Model 2		
	OR	95% CI	*p*	OR	95% CI	*p*
Age (45–59 yr)	1.000			-	-	-
Age (60–74 yr)	3.748	1.481–9.487	0.005	-	-	-
Age (≥75 yr)	4.239	1.555–11.561	0.005	-	-	-
BMI (<24 kg/cm^2)	3.794	1.716–8.387	0.001	-	-	-
ALB (<40 g/L)	5.312	2.397–11.772	<0.001	5.408	2.577–11.347	<0.001
HbA1c (>7%)	3.589	1.538–8.374	0.003	4.195	1.871–9.402	<0.001
Albuminuria	5.283	2.354–11.859	<0.001	4.823	2.311–10.066	<0.001
NAFLD	4.562	1.987–10.474	<0.001	3.439	1.637–7.227	<0.001
Insulin	0.270	0.119–0.609	0.002	-	-	-

Note: Model 1, multivariable logistic analysis; Model 2, corrected for age and BMI. BMI: body mass index; ALB: serum albumin; HbA1c: glycosylated hemoglobin A1c; NAFLD: non-alcoholic fatty liver disease; OR: odds ratio; CI: confidence interval.

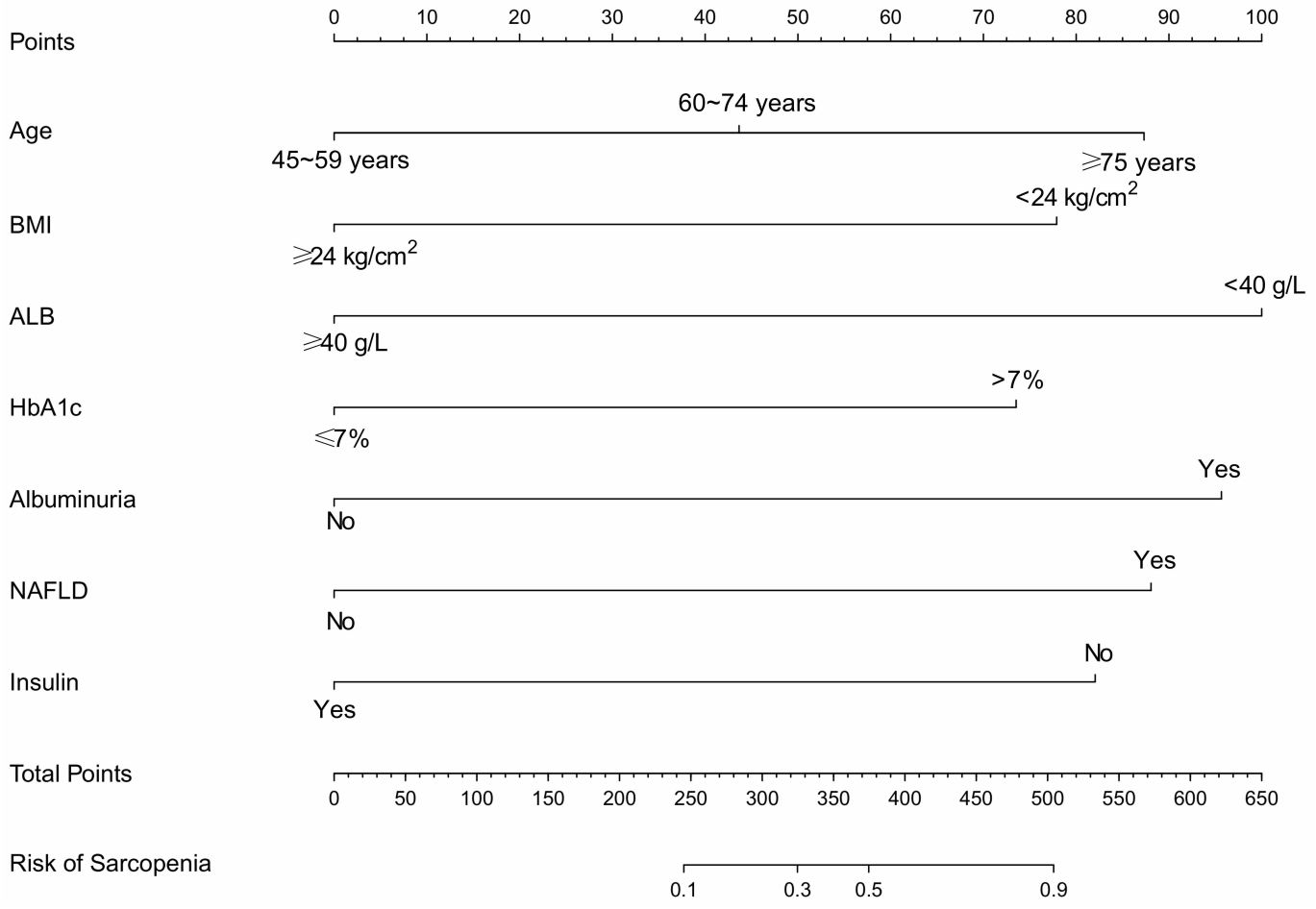

FIGURE 1. Nomogram predicting sarcopenia in T2DM men. BMI: body mass index; ALB: serum albumin; HbA1c: glycosylated hemoglobin A1c; NAFLD: non-alcoholic fatty liver disease.

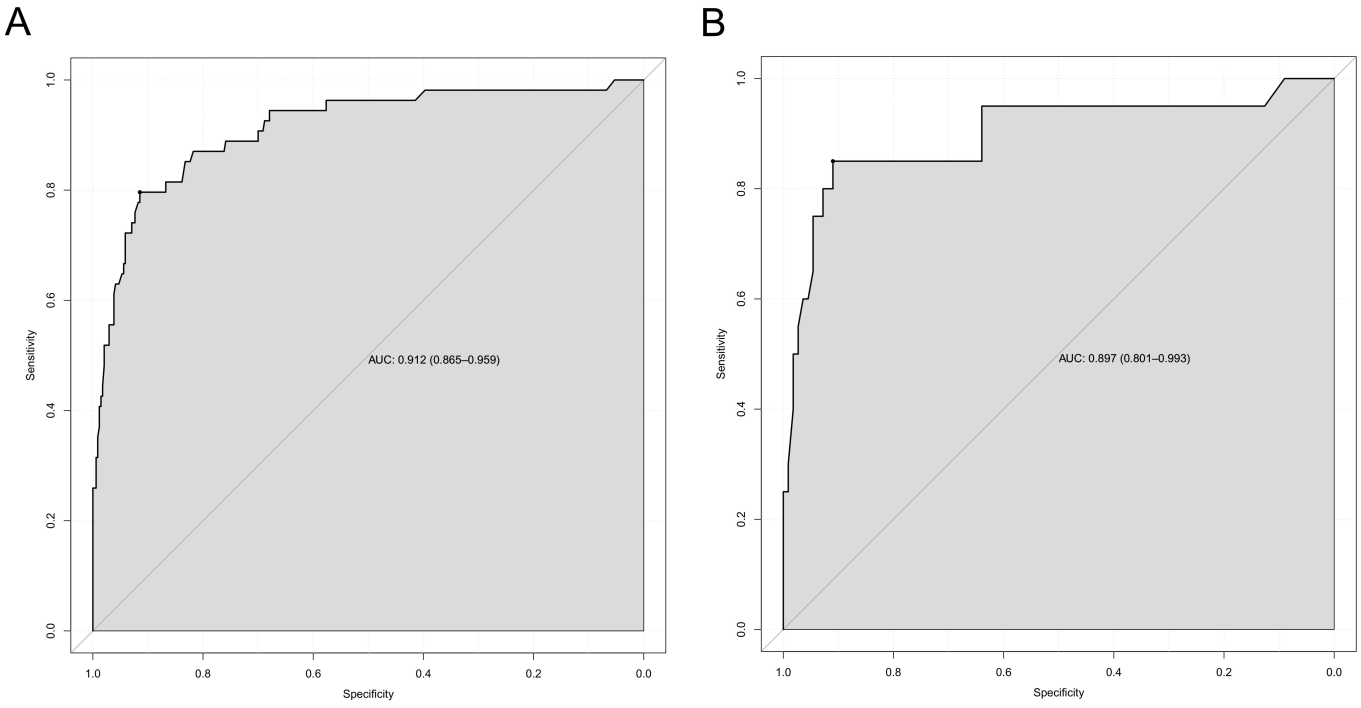

FIGURE 2. ROC curve of the predictive nomogram for the risk of sarcopenia in T2DM. (A) Training cohort. (B) Validation cohort. AUC: area under the receiver operating characteristic curve.

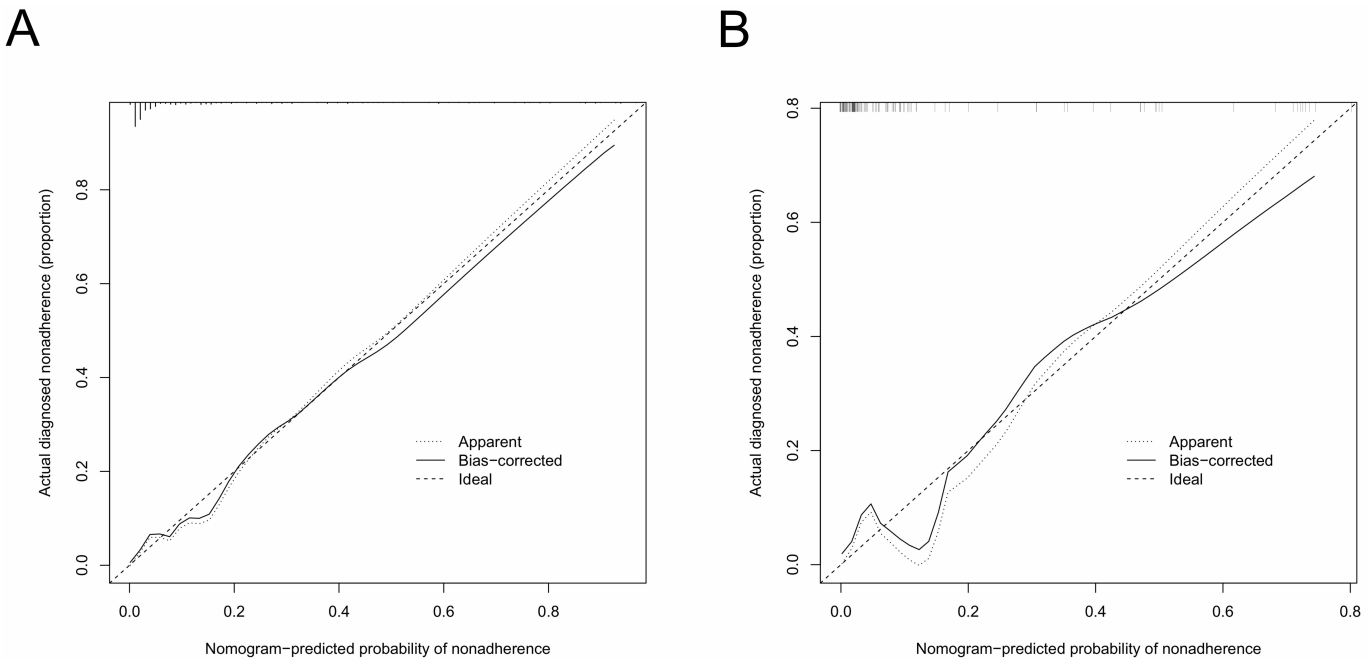

FIGURE 3. Calibration curve for predicting the risk of sarcopenia in T2DM. (A) Training cohort. (B) Validation cohort.

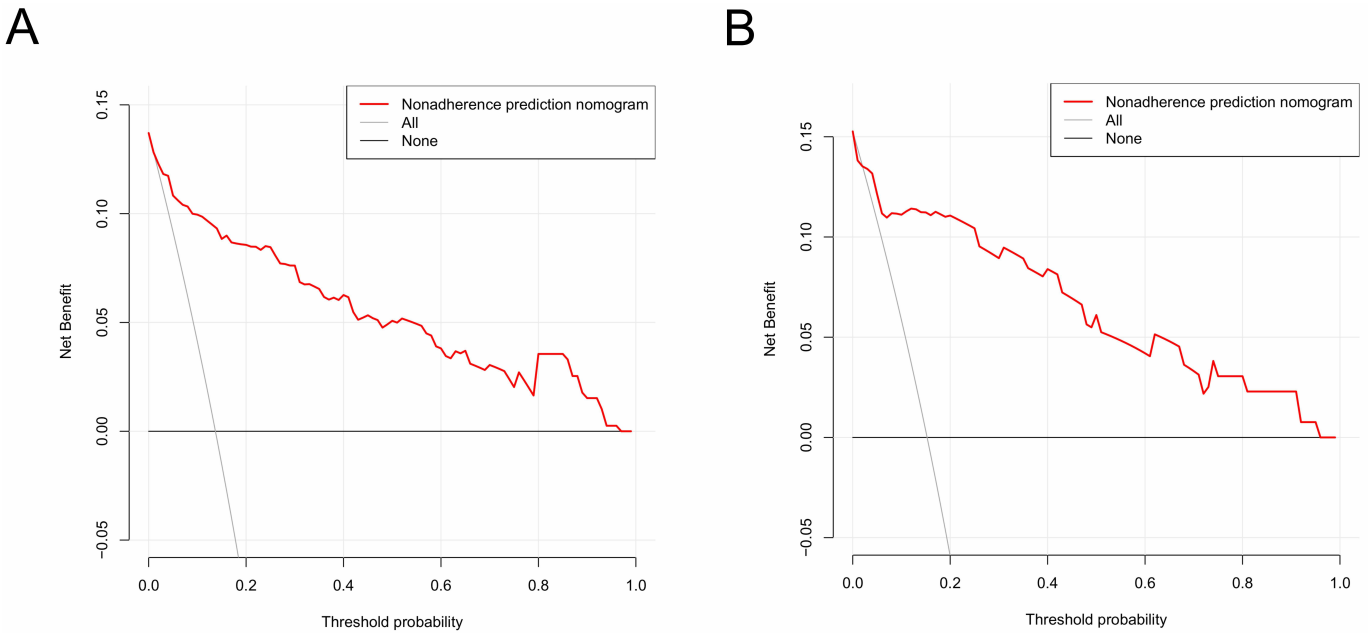

FIGURE 4. Decision curve analysis for predicting the risk of sarcopenia in T2DM. (A) Training cohort. (B) Validation cohort.

betes, albuminuria continued to be an independent risk factor for the development of sarcopenia even when confounding variables were taken into account. It has been shown that glomerular endothelial cell failure, glomerular hyperfiltration, and increased tubular permeability caused by insulin resistance all result in albuminuria [24, 25]. Conversely, glomerular endothelial cell dysfunction in albuminuria individuals may result in aberrant vasodilatation and increased infiltration of inflammatory cells, raising the risk of albuminuria [26]. All of the aforementioned scenarios may represent the mechanism through which albuminuria develops as a result of sarcopenia, though further research is needed to confirm this.

Emerging evidence suggests that sarcopenia and NAFLD share similar risk factors and common pathological mechanisms. It has recently been demonstrated that sarcopenia and NAFLD are independently correlated [27] and that sarcopenia increases the prevalence of NAFLD [28]. In the context of NAFLD, fat accumulation in muscle tissue promotes a pro-inflammatory cascade and oxidative stress, leading to mitochondrial dysfunction, impaired insulin signaling and muscle atrophy. Reduced muscle mass exacerbates insulin resistance and the interaction between muscle factors and adipokines leads to negative feedback, further aggravating sarcopenia obesity and insulin resistance [29]. Men are more likely than women to develop NAFLD, suggesting that gender disparities also influence the disease's pathophysiology [30]. Testos-

terone is a powerful anabolic androgen that gradually decreases with male age [31]. Low testosterone levels are linked to sarcopenia, insulin resistance, and non-alcoholic fatty liver disease (NAFLD) in males [32]. These above findings may well explain the significant correlation between NAFLD and sarcopenia in male T2DM patients in this study.

The nomogram is a statistical model for individualized predictive analysis of clinical events. Compared to other predictive statistical methods, the nomogram model can provide better individualized predictive risk assessment intuitively and visually [33]. Li *et al*. [34] developed a nomogram predicting the diagnosis of pre-diabetic sarcopenia in young people based on gender, height, and waist circumference. However, the construction of a corresponding prediction model for middle-aged and older men with T2DM has not been previously reported. This study identified seven influencing factors through multifactorial logistic regression analyses which are routine clinical variables readily available to clinicians, making them easy to implement in practice. Additionally, eligible patients were divided into a training cohort and a validation cohort using random sampling to evaluate the efficacy of the prediction model. In the training cohort, the AUC for predicting nomogram was 0.912, suggesting good predictive efficacy. When the established prediction model was externally validated, it had good efficacy in both prediction accuracy and calibration curves and DCA, suggesting that the prediction model was a good evaluation tool.

This study identified risk variables associated with sarcopenia in male T2DM patients and constructed a prediction model specifically for middle-aged and older men. However, there are several limitations to this study. First, it did not include a control group of non-diabetic individuals. Additionally, rather than being the outcomes of a multicenter large-sample epidemiological survey, this study is a single-center retrospective analysis, which may introduce selection bias. Further multicenter prospective studies are required to confirm the reliability of the prediction model. Moreover, this study cannot establish causal relationships such as causes and effects.

5. Conclusions

In conclusion, age $\geq$60 years, BMI $<$24kg/m^2, ALB $<$40 g/L, HbA1c $>$7%, albuminuria, NAFLD, and insulin use were all independent factors influencing the development of sarcopenia in newly diagnosed middle-aged and elderly men with T2DM. The nomogram model constructed on the basis of the above indicators has good diagnostic efficacy for the occurrence of sarcopenia in newly diagnosed middle-aged and elderly men with T2DM and may provide a potential non-invasive tool for sarcopenia screening.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

JC, YG—designed the study and carried them out, prepared the manuscript for publication and reviewed the draft of the manuscript. JC, JMQ, YRL, HYL, CPL, YG—supervised the data collection, analyzed the data. JC, JMQ, YRL, YG—interpreted the data. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of The People's Hospital of Shijiazhuang (Approval no. 2024-010). Written informed consent was obtained from a legally authorized representative for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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