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ORIGINAL RESEARCH

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Construction of a logistic regression-based risk prediction model for male patients with type 2 diabetes mellitus complicated by sarcopenia and validation of its efficacy

Jing Cai[1,*], Jingmin Qiao[1], Yiran Liu[1], Hongyan Li[1], Caiping Lu[1], Ying Gao[1]

[1]Department of Endocrinology, The People's Hospital of Shijiazhuang, 050011 Shijiazhuang, Hebei, China

***Correspondence**
cj_dr11@163.com
(Jing Cai)

Abstract

This study aimed to construct a risk prediction model for male patients diagnosed with type 2 diabetes mellitus and sarcopenia, and subsequently assess its effectiveness in predicting efficacy. The study subjects consisted of male patients diagnosed with type 2 diabetes who were admitted to the hospital between August 2023 and February 2024. The participants were categorized into two groups: the sarcopenic group (n = 92) and the non-sarcopenic group (n = 196). Patients' clinical data, lifestyle habits, comorbidities, medical history, and laboratory test markers were collected and subjected to statistical analysis. The findings from both univariate and multivariate logistic regression analyses indicate that age and uric acid (UA) are associated with an increased risk of developing sarcopenia in male patients with type 2 diabetes mellitus. Conversely, Body Mass Index (BMI) and vitamin D are associated with a decreased risk of sarcopenia in men with type 2 diabetes. The probability model for predicting the risk of Sarcopenia in male patients with type 2 diabetes: $P = 1/[1 + \exp(4.227 - 2.029X_1 - 1.165X_2 + 0.752X_3 + 0.216X_4)]$. Hosmer and Lemeshow's goodness-of-fit test showed that $\chi^2 = 7.993$, $p = 0.434$. Receiver Operator Characteristic Curve (ROC) curve analysis showed that Area Under the curve (AUC) was 0.911, 95% Confidence Interval (CI) was 0.879–0.944 respectively. The probability model value was 0.88, which is greater than 0.5, as indicated by the analysis of the overall model quality result. A high clinical predictive value was demonstrated by the risk prediction model of type 2 diabetes mellitus with sarcopenia, which can be used to facilitate early intervention and prevention of the disease.

Keywords

Logistic regression analysis; Type 2 diabetes mellitus; Sarcopenia; Risk prediction; Model building

1. Introduction

Sarcopenia is a condition characterized by a decrease in muscle mass, stamina and function that is associated with aging. It mainly affects the elderly, but it also occurs in people of other age groups [1]. Muscle weakness, diminished strength, increased susceptibility to exhaustion, and an elevated risk of falls are the primary symptoms of sarcopenia. These symptoms can impede daily activities, including walking, ascending and descending stairs, waking up, and dressing [2]. In addition to increasing the likelihood of falls, fractures, hospitalization, and death, sarcopenia also impacts the quality-of-life of patients. Sarcopenia is significantly correlated with the development of type 2 diabetes mellitus (T2DM), a prevalent chronic metabolic disorder. As a consequence of insulin resistance and hyperglycemia, patients with T2DM experience decreased protein synthesis and increased catabolism, which promotes muscle atrophy and dysfunction [3]. Furthermore, patients with T2DM frequently have comorbidities, including hypertension, hyperlipidemia, and obesity, which can exacerbate the development of sarcopenia. The management of diabetic patients is contingent upon the early identification and intervention of sarcopenia. Research has demonstrated that male diabetic patients are at an increased risk of developing complications of sarcopenia, which is associated with their physiological characteristics and lifestyle [4]. Consequently, it is imperative to conduct research on male patients in order to gain a more comprehensive understanding of the mechanism, prevention and treatment of sarcopenia. The current method of predicting sarcopenia complications in male diabetic patients is primarily based on clinical indicators and laboratory tests, but their accuracy is subpar [5]. Thus, it is imperative to create

a prediction model that is more sensitive and precise in order to assist clinicians in identifying and intervening during the early stages of sarcopenia. This study aimed to construct a risk model capable of predicting sarcopenia in male patients with type 2 diabetes mellitus.

2. Study subjects and methods

2.1 Study subjects

The study subjects were male patients with type 2 diabetes mellitus who were admitted to the hospital between August 2023 and December 2023. Patients were grouped based on whether they had sarcopenia, resulting in a sarcopenic group (n = 92) and a non-sarcopenic group (n = 196). The patients' ages ranged from 60 to 70 years.

2.1.1 Inclusion criteria

1. The Strength, assistance with walking, rising from a chair, climbing stairs, and falls (SARC-F) questionnaire was used for the preliminary screening, or simpler physical function assessment instruments like grip strength and gait speed were used. If the results of the first screening are positive, additional muscle mass and strength testing was carried out in accordance with the guidelines suggested by the European Working Group on Sarcopenia in Older People (EWGSOP2).

For males, skeletal muscle mass index (SMI) $<$7.0 kg/m^2, grip strength $<$28 kg, or gait speed $<$1 m/s; for females, SMI $<$5.7 kg/m^2, grip strength $<$18 kg, or gait speed $<$1 m/s.

2. Age $\geq$40 years.

3. Ability to cooperate with relevant tests and assessments.

2.1.2 Exclusion criteria

1. Presence of diseases that could lead to muscle loss, such as chronic diseases (chronic heart failure, chronic obstructive pulmonary disease, diabetes, chronic kidney disease, liver cirrhosis, *etc.*), metabolic and endocrine diseases (hypothyroidism, Cushing's syndrome, growth hormone deficiency, inflammatory and autoimmune diseases, rheumatoid arthritis, systemic lupus erythematosus, *etc.*), and neurological diseases (Parkinson's disease, multiple sclerosis, amyotrophic lateral sclerosis, *etc.*).

2. Presence of malignancies, infectious diseases, autoimmune diseases, or other conditions affecting muscle quality and function.

3. Poor lifestyle habits such as smoking or excessive alcohol consumption.

4. Presence of other musculoskeletal diseases.

5. Poor lifestyle habits such as smoking or excessive alcohol consumption.

Based on the exclusion criteria, 33 patients in the sarcopenic group and 69 patients in the non-sarcopenic group were excluded from the study.

2.2 Methods

Clinical data, lifestyle habits, treatment conditions, comorbidities, medical history, and laboratory test indicators of patients were recorded using a self-designed form from our hospital.

(1) Weight measurement method

- Equipment: Use a calibrated electronic or mechanical scale.

- Environment: Ensure the scale is on a hard, flat surface, avoiding carpets or uneven surfaces.

- Clothing: The subject should wear light clothing, removing shoes and outerwear if possible.

The procedure is as follows:

- Power on and zero: For electronic scales, ensure it displays zero after turning the scale on. For mechanical scales, ensure the pointer is at zero.

- Standing position: The subject should stand in the center of the scale, feet naturally apart, balanced and still.

- Record weight: Once the reading stabilizes, record the weight, accurate to one decimal place (*e.g.*, XX.X kg).

(2) Height measurement method

- Equipment: Use a standard stadiometer or a fixed wall-mounted height gauge.

- Environment: Ensure the measuring wall or height gauge is perpendicular to the floor, and the floor is level.

The procedure is as follows:

- Remove shoes: The subject should remove shoes, hats and any headgear that might affect the measurement.

- Standing position: The subject's back, head, shoulder blades, buttocks and heels should touch the wall or height gauge.

- Head position: The subject should stand naturally with the head straight and eyes level (Frankfurt plane).

- Heel position: Heels together with toes slightly apart in a "V" shape.

- Adjust height gauge: If using an adjustable gauge, lower the measuring rod or crossbar gently to touch the top of the subject's head, ensuring parallel contact.

- Record height: Read and record the height from the gauge or wall marks, accurate to one decimal place (*e.g.*, XX.X cm).

Laboratory test indicators include: lipid profile (total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglycerides (TG)), glucose indicators (fasting blood glucose (FBG), serum C-peptide (FCP)), bone metabolism markers (total type I collagen amino-terminal propeptide (TPINP), osteocalcin (OC), β-collagen degradation products (β-CTX), 25-hydroxyvitamin D (25(OH)D)), vitamin D, bone density, uric acid (UA), estimated glomerular filtration rate (eGFR), and homeostatic model assessment for insulin resistance (HOMA-IR). All data have been reviewed and approved by a biostatistician.

2.3 Statistical analysis

The analysis was conducted using SPSS version 27.0 (International Business Machines Corporation, Armonk, NY, USA). The measurement data were analyzed using the *t*-test, while the count data were assessed using the χ^2 test. A binary logistic regression analysis model was utilized to conduct multifactor regression analysis. The Hosmer and Lemeshow test was employed to assess the goodness-of-fit of the probability model. The ROC curve was generated using SPSS to assess the predictive power of the prediction model. $p < 0.05$, indicates

a statistically significant difference. The data presented in this work have been reviewed and approved by biostatisticians.

3. Results

3.1 Univariate analysis

The sarcopenic group had higher age, uric acid (UA), estimated glomerular filtration rate (eGFR), and homeostatic model assessment for insulin resistance (HOMA-IR) compared to the non-sarcopenic group. Conversely, the sarcopenic group had lower BMI, vitamin D levels, and bone density than the non-sarcopenic group, with significant differences ($p < 0.05$) as seen in Table 1.

3.2 Logistic multifactorial regression analysis

Age and UA were found to differ significantly ($p < 0.05$) by the logistic regression model, with an odds ratio (OR) greater than one. There was a statistically significant difference between the BMI and vitamin D ($p < 0.05$), with an OR value less than one. Thus, it was established that, age and UA are risk factors for the development of Sarcopenia in male patients with type 2 diabetes mellitus. Table 2 shows that BMI and vitamin D are protective variables for type 2 diabetes mellitus exacerbated by Sarcopenia in male patients.

3.3 Risk prediction model for men with type 2 diabetes complicated by sarcopenia

The binary logistic multifactor regression analysis model was as follows: Logit (P) = $\ln[P/(1 - P)] = -4.227 + 2.029X_1 + 1.165X_2 - 0.752X_3 - 0.216X_4$.

Probability model for predicting the risk of Sarcopenia in males with type 2 diabetes mellitus: $P = 1/[1 + \exp(4.227 - 2.029X_1 - 1.165X_2 + 0.752X_3 + 0.216X_4)]$.

3.4 Goodness of fit test

The goodness-of-fit test of the probability model was conducted using Hosmer and Lemeshow, and the results showed that $\chi^2 = 7.993$, $p = 0.434$, which indicates that the probability model is well-fitted as seen in Table 3.

3.5 ROC curve analysis

ROC curve analysis shows that the prediction model has significant predictive value ($p < 0.05$), with an AUC of 0.929 and a 95% confidence interval of 0.870 to 0.989 as seen in Table 4.

4. Discussion

This article analyzes the differences between sarcopenic and non-sarcopenic patients based on clinical data, lifestyle habits, comorbidities, medical history and laboratory indicators (such as lipid profile, glucose levels, vitamin D, bone density and uric acid) in male patients with type 2 diabetes. It constructs a risk prediction model for sarcopenia in male type 2 diabetes patients based on logistic regression analysis. The results show that age and uric acid (UA) are risk factors for sarcopenia in male type 2 diabetes patients, while BMI and vitamin D are protective factors.

Type 2 diabetes is a common chronic disease characterized by hyperglycemia and pancreatic dysfunction. Sarcopenia, an age-related health issue, is also prevalent among patients with type 2 diabetes. Sarcopenia impacts patients' quality of life and increases the risk of falls, fractures, hospitalization and mortality [6]. Thus, early identification of the risk of sarcopenia in type 2 diabetes patients is crucial. Clinical research has found [7]; that the prevalence of sarcopenia is relatively higher in male patients with type 2 diabetes. Men have lower estrogen levels, which are believed to help with muscle maintenance, whereas women usually have higher estrogen levels before menopause, which helps protect muscle health. Some studies suggest that men are more likely to inherit genetic variations associated with sarcopenia, increasing their risk of developing the condition [8, 9]. Male patients generally outperform female patients in terms of average muscle mass, strength and physical fitness, but muscle mass decreases with aging. As a result, muscle loss is more apparent in male patients and more prone to progress to sarcopenia. This study focuses on male patients, which will help to improve understanding of the risk factors and prediction models for sarcopenia in male patients. The study analyzed clinical data, lifestyle habits, comorbidities, medical history and laboratory indicators (lipid levels, blood glucose, vitamin D, bone density, uric acid) of male patients with type 2 diabetes to examine differences between those with and without sarcopenia. A logistic regression analysis was used to construct a risk prediction model for sarcopenia in male patients with type 2 diabetes. The results indicate that age and uric acid are risk factors for sarcopenia in male patients with type 2 diabetes, while BMI and vitamin D are protective factors.

4.1 The relationship between age and sarcopenia in male patients with type 2 diabetes

Age is a significant risk factor for sarcopenia in male patients with type 2 diabetes. As men age, they are more likely to develop type 2 diabetes and are also at higher risk for sarcopenia. This perspective is supported by multiple studies and aligns with the relationship between age and muscle health [10]. Studies have found that muscle mass and function gradually decline with age, while the prevalence of sarcopenia increases [10]. Research indicates that in men over 40, the incidence of sarcopenia rises rapidly, peaking after the age of 70 [11]. Age is a crucial factor affecting muscle mass and function in patients with type 2 diabetes. Research results have shown that, with increasing age, muscle mass and function in type 2 diabetes patients significantly decline [11].

4.2 The relationship between uric acid and sarcopenia in male patients with type 2 diabetes

There is a notable relationship between uric acid (UA) levels and sarcopenia in male patients with type 2 diabetes. Elevated uric acid levels are associated with inflammation, oxidative stress, and insulin resistance, which in turn increase the risk

TABLE 1. Data for univariate analysis.

Indicators	Sarcopenic group (n = 92)	Non-Sarcopenic group (n = 196)	χ^2/t	p value
Age (yr)	66.35 ± 5.11	60.44 ± 4.86	9.465	<0.001
BMI (kg/m^2)	24.15 ± 0.25	26.19 ± 0.27	61.190	<0.001
Duration of Illness (yr)	11.25 ± 1.22	11.15 ± 1.15	0.675	0.252
Smoking history (n, %)				
Yes	33, 35.87	66, 33.67	0.134	0.714
No	59, 64.13	130, 66.33		
History of alcohol consumption (n, %)				
Yes	35, 38.04	77, 39.29	0.041	0.840
No	57, 61.96	119, 60.71		
Comorbid hypertension (n, %)				
Yes	34, 36.96	70, 35.71	0.042	0.838
No	58, 63.04	126, 64.29		
Comorbid hyperlipidemia (n, %)				
Yes	31, 33.70	66, 33.67	0.000	0.997
No	61, 66.30	130, 66.33		
Oral hypoglycemic drugs (n, %)				
Yes	71, 77.17	141, 71.94	0.883	0.347
No	21, 22.83	55, 28.06		
Insulin (n, %)				
Yes	38, 41.30	80, 40.82	0.006	0.937
No	54, 58.30	116, 59.18		
TC (mmol/L)	6.18 ± 0.69	6.17 ± 0.51	0.138	0.445
LDL-C (mmol/L)	2.63 ± 0.22	2.62 ± 0.26	0.319	0.376
HDL-C (mmol/L)	1.31 ± 0.12	1.32 ± 0.19	0.463	0.323
TG (mmol/L)	1.81 ± 0.16	1.79 ± 0.15	1.033	0.154
UA (mmol/L)	356.35 ± 34.26	300.25 ± 29.68	14.223	<0.001
FBG (mmol/L)	7.71 ± 0.69	7.69 ± 0.59	0.254	0.400
FCP (μg/L)	1.41 ± 0.13	1.42 ± 0.15	0.550	0.293
TPINP (ng/mL)	39.25 ± 3.26	39.28 ± 3.27	0.073	0.471
OC (ng/mL)	12.74 ± 1.24	12.76 ± 1.26	0.126	0.450
β-CTX (ng/mL)	0.41 ± 0.05	0.40 ± 0.05	1.583	0.060
25(OH)D (ng/mL)	19.25 ± 1.65	19.33 ± 1.69	0.377	0.354
eGFR (mL/min)	19.25 ± 1.65	99.56 ± 9.25	8.070	<0.001
HOMA-IR	109.25 ± 10.02	2.14 ± 0.55	3.3103	<0.001
Vitamin D (mg/L)	2.36 ± 0.47	15.24 ± 1.48	16.507	<0.001
Bone density (g/cm^2)	0.91 ± 0.09	1.22 ± 0.11	23.574	<0.001

Note: BMI: Body Mass Index; TC: Total Cholesterol; LDL-C: Low-Density Lipoprotein Cholesterol; HDL-C: High-Density Lipoprotein Cholesterol; TG: Triglycerides; UA: Uric Acid; FBG: Fasting Blood Glucose; FCP: Fasting C-Peptide; TPINP: Total Procollagen Type I N-Terminal Propeptide; OC: Osteocalcin; β-CTX: Beta-CrossLaps (Beta-C-Terminal Telopeptide of Type I Collagen); 25(OH)D: 25-Hydroxyvitamin D; eGFR: Estimated Glomerular Filtration Rate; HOMA-IR: Homeostatic Model Assessment for Insulin Resistance.

TABLE 2. Data for Logistic multifactorial regression analysis.

Indicators	β	Standard error	wald	p	OR value	OR value of 95% Confidence Interval	
						Lower Limit	Upper Limit
Age	2.029	0.615	10.903	0.001	7.608	2.281	25.371
UA	1.165	0.549	4.511	0.034	3.207	1.094	9.402
BMI	−0.752	0.206	13.344	<0.001	0.471	0.315	0.706
Vitamin D	−0.216	0.082	7.002	0.008	0.805	0.686	0.945
Constant	−4.227	0.737	32.889	<0.001	0.015		

Note: UA: Uric Acid; BMI: Body Mass Index; OR: Odds Ratio.

TABLE 3. Hosmer-Lemeshow test for probabilistic models.

χ^2	Degree of freedom	p
7.993	8	0.434

of developing sarcopenia in these patients. One study found a link between uric acid levels and declines in muscle function as well as the development of sarcopenia. High uric acid levels are related to insulin resistance, which is one of the primary pathological mechanisms of type 2 diabetes [12]. Elevated uric acid levels are associated with decreased muscle mass and function and an increased risk of sarcopenia in type 2 diabetes patients. Research has also found that mitochondrial dysfunction may be related to the development of diabetes [13, 14].

4.3 The relationship between BMI and sarcopenia in male patients with type 2 diabetes

BMI plays a protective role in sarcopenia among male patients with type 2 diabetes. A higher BMI is associated with greater muscle mass, lower insulin resistance, and better nutritional status, which reduces the risk of developing sarcopenia in these patients. A higher BMI generally indicates more body weight, including muscle mass. BMI is positively correlated with muscle function and quality in type 2 diabetes patients [15]. A higher BMI suggests more muscle mass, thereby lowering the risk of sarcopenia. Additionally, a higher BMI is related to lower insulin resistance and better blood glucose control, reducing the risk of sarcopenia. It is also associated with better nutritional status and higher protein reserves, which help maintain muscle health [16].

4.4 The relationship between vitamin D and sarcopenia in male patients with type 2 diabetes

Vitamin D has a protective role in sarcopenia among male patients with type 2 diabetes. It is involved in muscle health, anti-inflammatory effects, and the regulation of insulin sensitivity, which reduces the risk of developing sarcopenia in these patients. Vitamin D is closely related to muscle health, playing a role in muscle protein synthesis, muscle function maintenance, and muscle strength regulation. Lower levels of vitamin D are associated with an increased risk of sarcopenia in type 2 diabetes patients [17]. Vitamin D has anti-inflammatory properties that can suppress chronic inflammation. Supplementing with vitamin D can improve the inflammatory state in type 2 diabetes patients, thereby reducing the risk of sarcopenia. Additionally, vitamin D regulates insulin signaling pathways, improving insulin sensitivity and lowering the risk of type 2 diabetes, which in turn reduces the risk of sarcopenia [18].

Based on these risk factors, this study used logistic regression analysis to construct a risk prediction model for sarcopenia in type 2 diabetes male patients. The model's goodness of fit was tested using Hosmer-Lemeshow, and its predictive value was analyzed with ROC curves. Results indicate that the model has good fit and significant predictive value. Overall, the analysis shows that the predictive value of the probability model is strong.

4.5 Bone metabolism biomarkers and their relationship with sarcopenia in men with type 2 diabetes

Research has shown that there is a certain relationship between bone metabolism biomarkers and the occurrence and progression of sarcopenia. TPINP is a collagen metabolism marker that reflects the synthesis and degradation of bone collagen. In men with type 2 diabetes complicated by sarcopenia, TPINP levels are often elevated, which may be related to increased bone collagen synthesis. OC, or osteocalcin, reflects bone calcium deposition and absorption. In sarcopenia patients, OC levels are typically lower, possibly due to reduced calcium absorption. β-CTX is a marker of collagen degradation that reflects the breakdown of bone collagen. In sarcopenia patients, β-CTX levels may be elevated, which could be related to increased collagen degradation. 25(OH)D is a vitamin D metabolism marker that reflects vitamin D levels. In sarcopenia patients, 25(OH)D levels are generally lower, possibly due to vitamin D deficiency. However, this study did not reach similar conclusions, which could be influenced by biological rhythms, hormones and medications. Research in this area is limited, and further studies with larger sample sizes are needed to explore the relationship between bone metabolism biomarkers and sarcopenia.

Limitations of this study include constraints related to sample size and sources, as well as its single-center design, which introduces certain limitations. For example, factors such as specific cytokines and growth factors, chronic low-grade inflammation, and certain types and intensities of physical ac-

TABLE 4. ROC curve analysis.

Test outcome variables	Region	Standard Error	Asymptotic Significance	Asymptotic 95% Confidence Interval	
				Lower limit	Upper limit
Age	0.326	0.059	0.023	0.210	0.442
UA	0.205	0.061	0.000	0.086	0.325
BMI	0.307	0.060	0.012	0.189	0.425
Vitamin D	0.693	0.060	0.012	0.575	0.811
Joint Probability	0.929	0.030	0.000	0.870	0.989

UA: Uric Acid; BMI: Body Mass Index.

tivity might also influence sarcopenia in patients with type 2 diabetes, but this study did not include these variables. Additionally, the mechanisms by which the identified risk and protective factors affect sarcopenia in male patients with type 2 diabetes have not been thoroughly investigated. Further research is needed to explore the association between uric acid and muscle wasting, aiming for more scientifically robust conclusions. Furthermore, the methods for model development also require further optimization and refinement.

5. Conclusions

In summary, this study concluded that age and UA are risk factors for the development of sarcopenia in male patients with type 2 diabetes mellitus. However, BMI and vitamin D are protective factors for the development of sarcopenia in men with type 2 diabetes mellitus. The risk prediction model established in this study can assist in the timely intervention and prevention of sarcopenia in male patients diagnosed with type 2 diabetes mellitus.

Future research should aim to broaden the study population in order to obtain more comprehensive and unbiased conclusions. Additionally, it is important to perform in-depth investigations into the mechanisms by which influencing factors affect the development of type 2 diabetes mellitus in male patients.

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—designed the study and carried them out. JC, JMQ, YRL, HYL, CPL—supervised the data collection; prepared the manuscript for publication and reviewed the draft of the manuscript. JC, JMQ, YRL, HYL, YG—analyzed the data, 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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